Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

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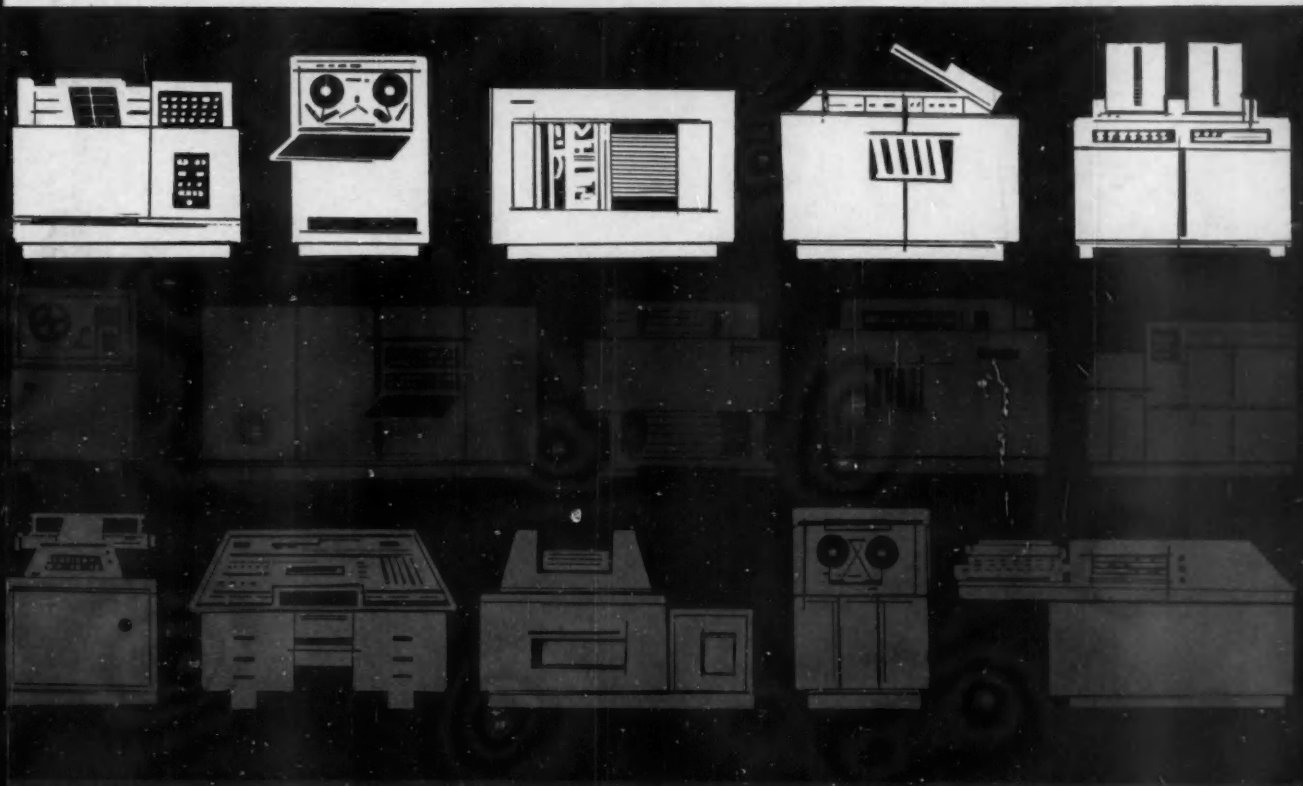
OCTOBER 1961



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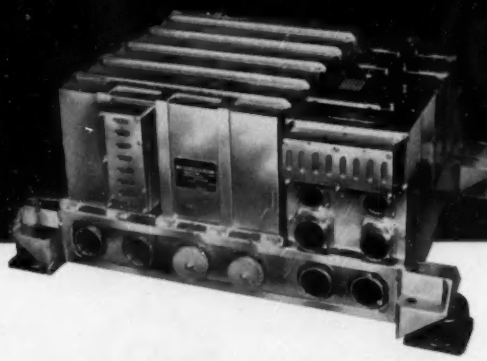

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that pace man's expanding mind

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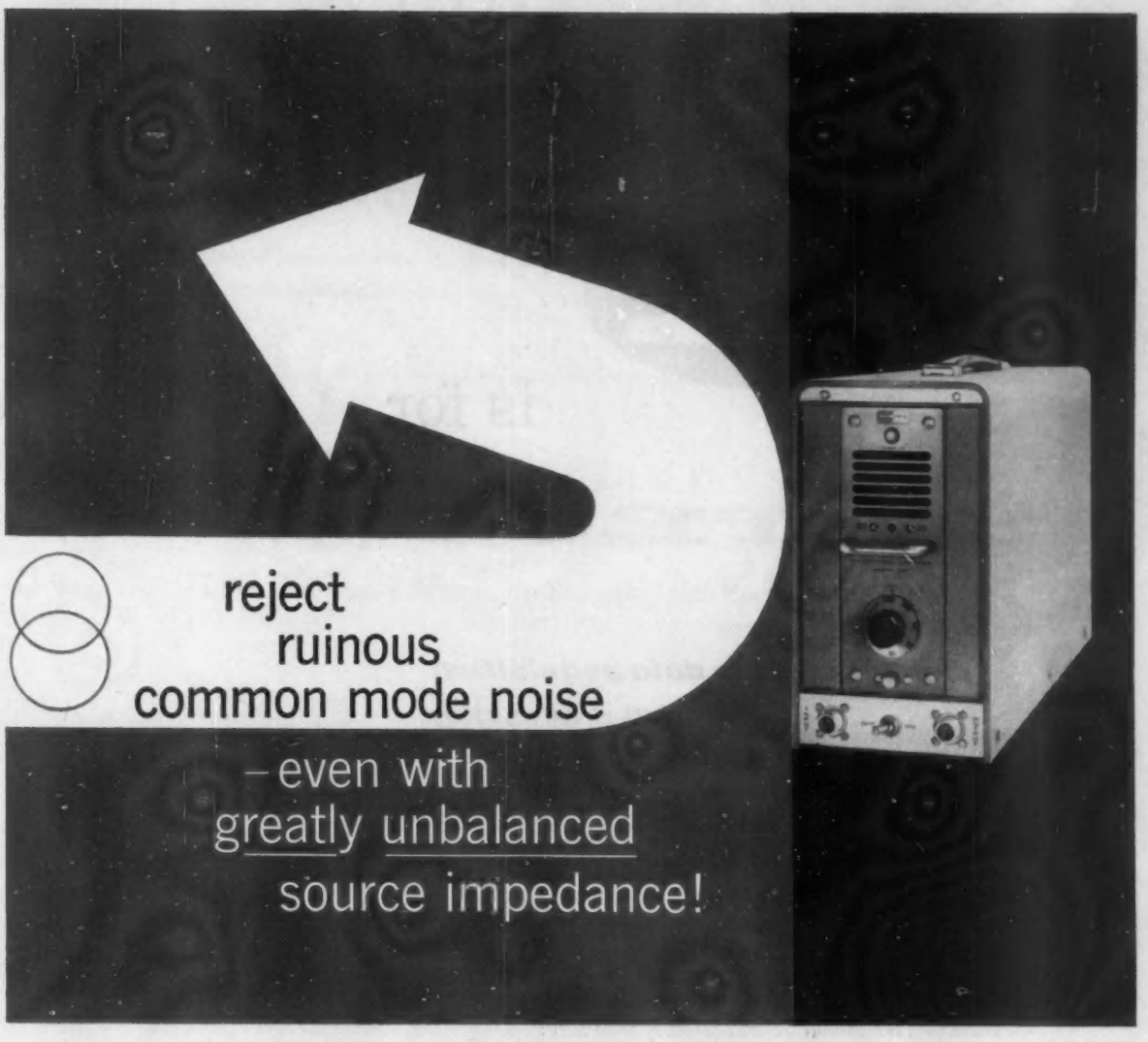

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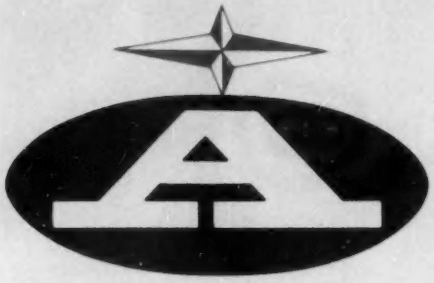

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Successors to Epsco-West

ANAHEIM, CALIFORNIA

Control ENGINEERING

OCTOBER 1961
VOL. 8 NO. 10

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

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PERIOD
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FREQUENCY OUTPUTS
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Kollsman's new Size 8 Synchronous Motors have a high "precision to ruggedness" ratio . . . were specifically designed for small space and light weight. Ungeared unit weighs only 1.25 oz. ■ These subminiature units are ideal for high reliability, high-performance applications in computer systems, camera drives, scanning devices, and other missile/avionics equipment. ■ Measuring only .960" length (ungeared), 2 5/32" (geared), the new Size 8's feature a synchronous speed of 8,000 rpm with a 400 cps input; source voltage is 55 volts; total power input is 5 watts; pull-in torque is .025 oz. in. Gear boxes available in ratios from 5:1 to 20,000:1. ■ You can now design your equipment or system smaller and better with a Kollsman Motor. Kollsman sales engineers are ready to assist you whatever your motor design needs. Take advantage of their experience which covers over 1,000 motor designs . . . which will save you time and money.

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Control ENGINEERING

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Published for engineers and technical management men responsible for the design, application, and test of automatic control systems.

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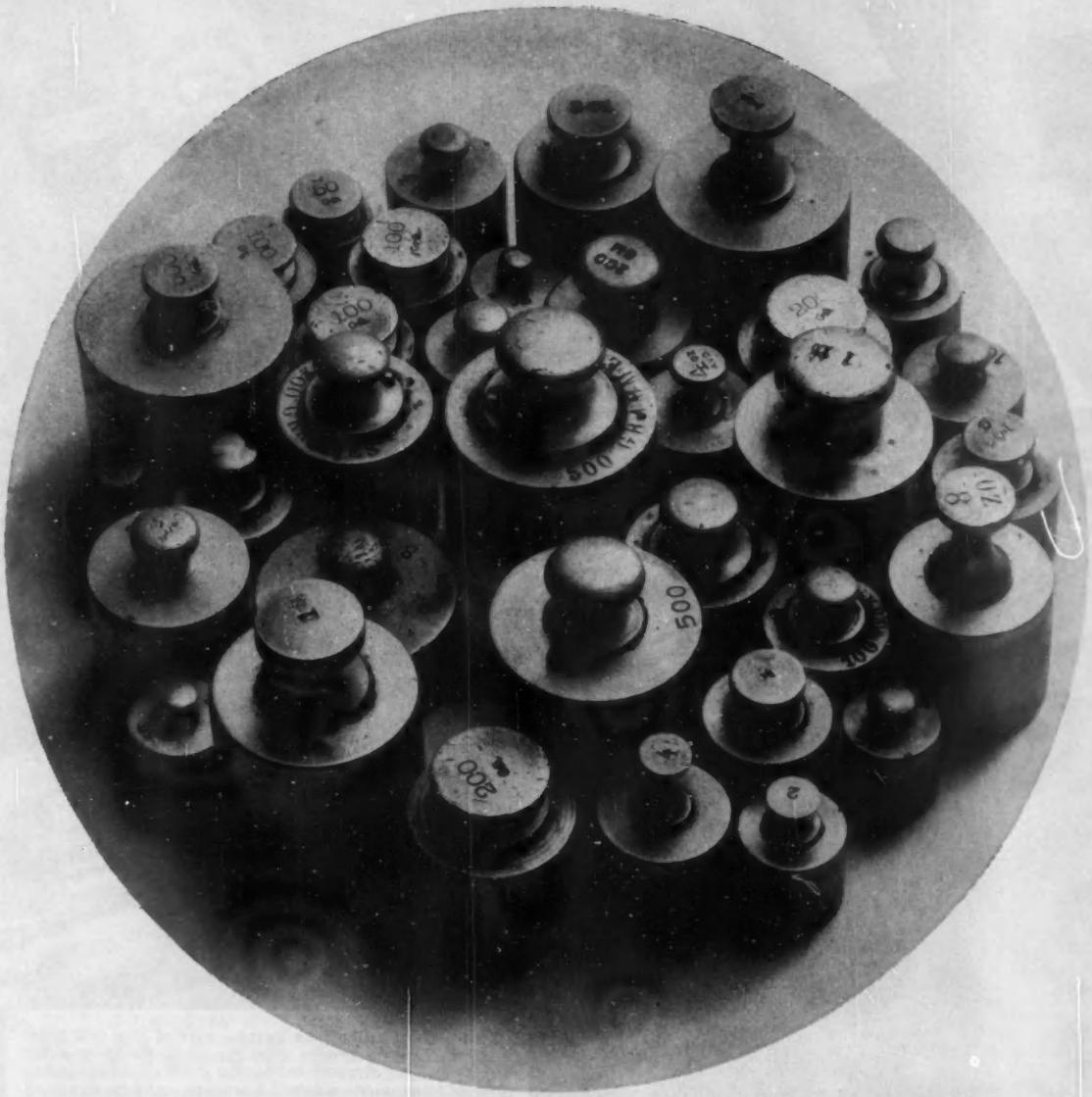

Count different sizes and weights the easy way—with a Veeder-Root High Speed Magnetic Counter. Once it was virtually impossible to record things both large or tiny, heavy or featherweight with electric counters. Nowadays, Veeder-Root magnetic counters do it at high speed and deliver remote readout data for centralized control. Design them into new machines or use them on existing equipment. You'll find them compact, reliable, simple to install. Need details? Write Electrical Section, Veeder-Root Incorporated, Hartford 2, Conn.

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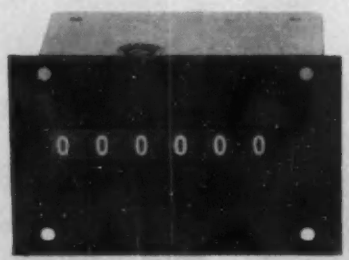
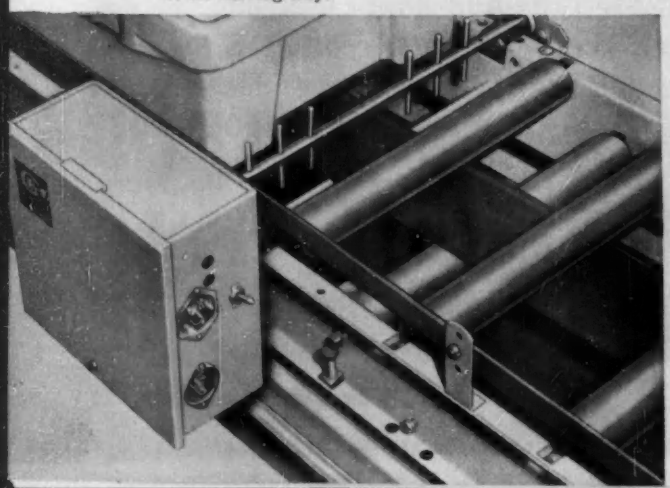


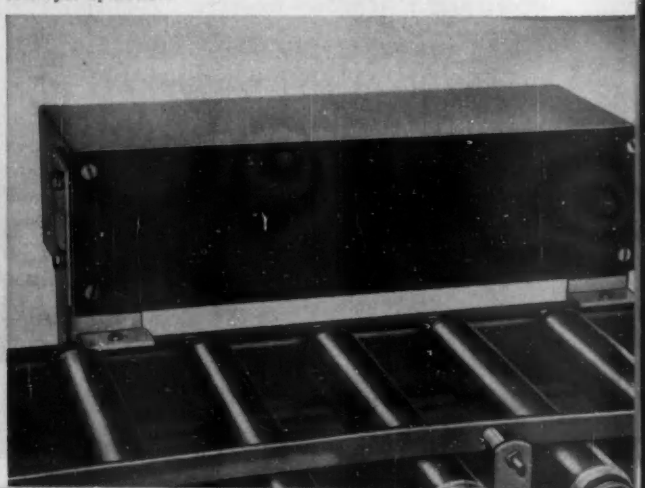
FREE — a new bulletin on Series 1591 counters. Get key facts on how these electrically actuated counters report machine output from factory to office, and how they pay off on many other devices. Send for Bulletin 842.

"Skate wheel" diverters increase rate of flow and eliminate mechanical damage often caused by swinging metal arm diverters. Controller—designed with mechanical spring linkage to eliminate solenoid burnouts—may be mounted to either side of conveyor.

"Paddle wheel" tray stop eliminates pneumatic system and can be used as a spacer, counter or with a timer to release trays at programmed intervals. Paddle, spring-held to bottom of each passing tray, is operated by force of the moving tray.



Proximity type sensing heads, transistorized and plug-in, will read without failure at 5/8" to improve flow reliability. Passing reader cards disturb a field emitted by sensing head and produce output signals to control conveyor operation.



CONTROL

What's new in material handling control?

Make your conveyor system more efficient with these new diverters, proximity readers, stop-spacers.

These new Cutler-Hammer specialized components have been successfully applied in some of the most outstanding automated material handling systems in operation.

The "roller skate wheel" diverter, for example, can double conveyor capacity without increasing conveyor speed. By eliminating the space formerly required for swinging metal diverter arms, carrying capacity is increased . . . damage to tote pans from swinging diverters is eliminated.

Adding greatly increased flexibility, these new devices have proven their efficiency in the most demanding engineered systems. Now they're being made available to you for your special applications. Each of these components measures up to the same high quality standards you've gotten for so long from Cutler-Hammer limit switches, pushbuttons, motor starters and other control apparatus used on conveyor systems.

WHAT ELSE IS NEW AT CUTLER-HAMMER?

These new conveyor control devices are typical of the many improvements coming out of Cutler-Hammer's systems engineering experience. As new problems are tackled, new ideas for solutions mean more and more improved new products are developed. Why don't you call your Cutler-Hammer sales office soon for new ideas that can help you solve your material handling problems?

WHAT'S NEW? ASK . . .

CUTLER-HAMMER

CONTROL

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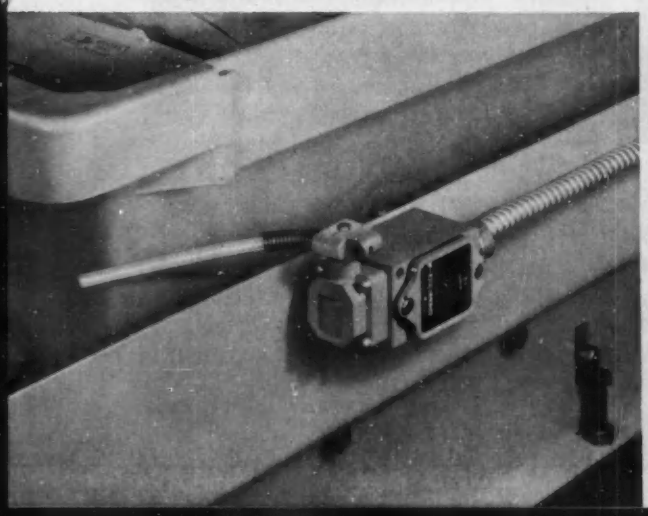
CIRCLE 9 ON READER SERVICE CARD

Limit switches. Many operator options to fit your particular need. New spring mounted nylon operator can be mounted on side of conveyor and is actuated by passing trays. Special design is tamper proof and eliminates multiple counts.



Graphic control consoles can be engineered to fit your application. This one is main console for a 6,000 ft. order-picking system. Anodized aluminum conveyor layout has control switches mounted to facilitate manual or semi-automatic operation.

This new answer to INDUSTRIAL REMOTE VIEWING PROBLEMS

cuts costs ... shortens delivery time

To overcome the problems in many industrial remote viewing applications involving water, gas, heat, pressure, radioactivity—Kollmorgen now offers precision modular periscopes. These American made instruments are available for almost immediate delivery. Contrary to many current price trends, modular periscopes are available at about one-third the cost of custom designed periscopes.

From precision components, the periscope assembles easily with only spanner wrench and screwdriver. A large assortment of varying tube lengths, elbows, eyepieces, and objectives, permit construction of numerous configurations. Completed periscopes can be reassembled into entirely different configurations to provide wide applicability.

Kollmorgen modular periscopes feature:

- **Low purchase price.**
- **Erect images at any angle of bend.**
- **Rugged construction for heavy duty, maintenance-free service.**
- **Sealed joints for use underwater.**
- **Easy mounting through, over or around walls, barriers, any viewing obstacles.**
- **Full warranty backed by fifty years of Kollmorgen quality in optical/electronic/mechanical systems.**

This Kollmorgen system is typical of solutions to specialized requirements. Write for illustrated brochure containing specifications. Write Department 510

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Digital computer equipment comparisons

In case you missed the significance of our striking front cover, it heralds the start of the most comprehensive comparisons of digital computer hardware ever published. Object of the series, reports Associate Editor Ed Kompass, is to provide a really useful aid to management and system engineers when deciding computer feasibility and selecting equipment best suited to particular needs.

Prepared by staff members of Cresap, McCormick and Paget, management consulting firm, each article in the series will list and compare performance of available equipment in a given category. Save your tearsheets (perforated for your convenience) of each article. They will add up to a handbook of comparative data on about 40 computers.

Enterprising reader files tearsheets with ease

A letter from Bob Gustafson says in part: "I imagine many engineers have filing folders filled with articles torn from CONTROL ENGINEERING. Too haphazard. I devised the Edge Binder (photo) that now makes indexing and filing in a three-ring binder easy. Perhaps other CtE readers would like to try them." How much? "A sample of 12 Edge Binders is $1. Quantity prices on request. Write to Argus Engineering, 698 S. York Rd., Elmhurst, Ill."

Stream analyzer specialist at Shell Development

Vigo N. Smith, author of "Predicting and Evaluating the Performance of Analytical Instruments" in this issue, didn't always work with analyzers for plant streams. After receiving an A.B. degree in Physics in 1939 from U. of California he stayed on until 1941 pursuing advanced studies. During the war Vigo worked at the Naval Research Lab (radar) and U. of C. Radiation Lab (Manhattan Project).

With Shell since 1945, Vigo has been active in development and application of infrared, ultraviolet, and radiological gas analyzers, and beta particle and special chromatographic instruments. In February, Vigo was named Assistant Head of Shell Development's Instrumentation Department.

under CONTROL

with Berkeley Division of Beckman Instruments, Inc.

Beckman Announces New Electronic Reversing Counters

With the new Beckman® solid-state 3300 Series of high-speed and preset reversing counters, reversing EPUT® and deviation EPUT meters, industry can now cope with numerous automatic control problems heretofore impractical or impossible to resolve with unidirectional counters. Digital reversing logic adds new dimensions to control systems engineering...providing faster, more accurate and efficient means of measuring, controlling, indicating, and computing by digital instrumentation.

Digital control systems employing direct-reading, solid-state reversing counters can be used in many industries – replacing slower, less reliable electromechanical devices or more complex electronic instrumentation.

Photo shows Model 3302/5 Dual Preset Reversing Counter.

Wide Application Range

Applications range from processing of raw materials to quality assurance of finished products. Typical applications include measuring and cutting to length in metal working; high speed rotary machine monitoring and control; flow process control; acceleration and velocity computation; and frequency deviation measurements.

What is a reversing counter? All of the direct-reading digital instruments in Beckman's 3300 Series are equipped with reversible decade counters, one for each digit of read-out. These units will count "up" in a conventional sequence of 0, 1, 2...9 and then, upon command, reverse to count "down" 9, 8...1, 0. If the count-down reaches a read-out of zero (before another command to reverse is received), the counters automatically reverse to a normal count-up sequence.

True Algebraic Sum

With this reversible counting logic, the digital read-out at any given time is always the true algebraic sum of "plus" and "minus" counts, which may represent forward and reverse travel, clockwise and counterclockwise rotation, quantities of input and output, or merely two distinct signals. The algebraic sign of the read-out is indicated by a "+" lamp or a "—" lamp, signifying that the read-out consists of more plus counts or minus counts, respectively.

Specific Applications

High-speed reversing counters are especially suitable for indicating precise increments of angular or linear bidirectional travel, as applied to positioning of antennae or automatic lathes. For rotary speed control applications in synthetic fiber or paper mills, these instruments can be used for monitoring lead/lag of two shafts or cylinders rotating at speeds greater than 50,000 rpm. In addition, a reversing counter will supply a DC control voltage corresponding to the "+" or "—" sign of the read-out for operating control relays and switches.

Preset reversing counters – single or dual – offer maximum utility for high-speed digital control applications, such as machine tool positioning, input/output control in automatic packaging, and flow-blend processing. The dual-preset feature can be used to prevent over-run in automatic machine tooling by providing a limit-warning signal preceded by a final positioning signal.

Reversing EPUT meters are capable of gathering data and simultaneously performing digital computations – without the need for converting input data to magnetic tape, punched tape or cards. In digital RPM measurements associated with testing of fluid coupling transmissions, the speed of the input shaft is compared with the output shaft for determining extremely accurate parameters.

Deviation EPUT meters provide a convenient means of computing carrier frequency deviation in calibrating FM telemetry systems. These versatile instruments can be used in numerous quality control applications in the electronics industry, such as the manufacturing of crystals, transistors, and high-stability oscillators.

Beckman Solid-state Reversing Counters

Model 3300 High-speed Reversing Counter

Basic high-speed reversing counter equipped with single input channel for counting "up" or "down" at rates up to 200,000 counts-per-second. External "sense" input reverses counting logic. With dual input channels, two distinct events (one can be considered plus, the other minus) can be counted simultaneously to derive true algebraic summation. Instruments available with read-out capacities of 3 to 6 digits. Binary-coded-decimal output also available for operating digital printers.

Model 3301 Single-preset Reversing Counter and Model 3302 Dual-preset Reversing Counter

In addition to features of the Model 3300, single-preset and dual-preset reversing counters provide contact closures to complete external circuits, pulses or changes in DC voltage levels when read-out reaches predetermined level. These predetermined levels are preset by digit selector switches, one for Model 3301 and two for 3302.

Model 3350 Reversing EPUT Meter

Model 3350 accumulates every cycle of plus or minus counts during precise time interval. Instrument also measures period of events in time units as short as 10 microseconds.

Model 3360 Deviation EPUT Meter

Instrument measures preselected read-out and then counts "down" to compute positive or negative deviation of unknown input frequency.

For additional information applying reversing counters to specific control problems, contact the Beckman/Berkeley Engineering Representative in your area or our Applications Engineers at Richmond. For additional data, ask for Technical Product Bulletin A3300.

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S-1

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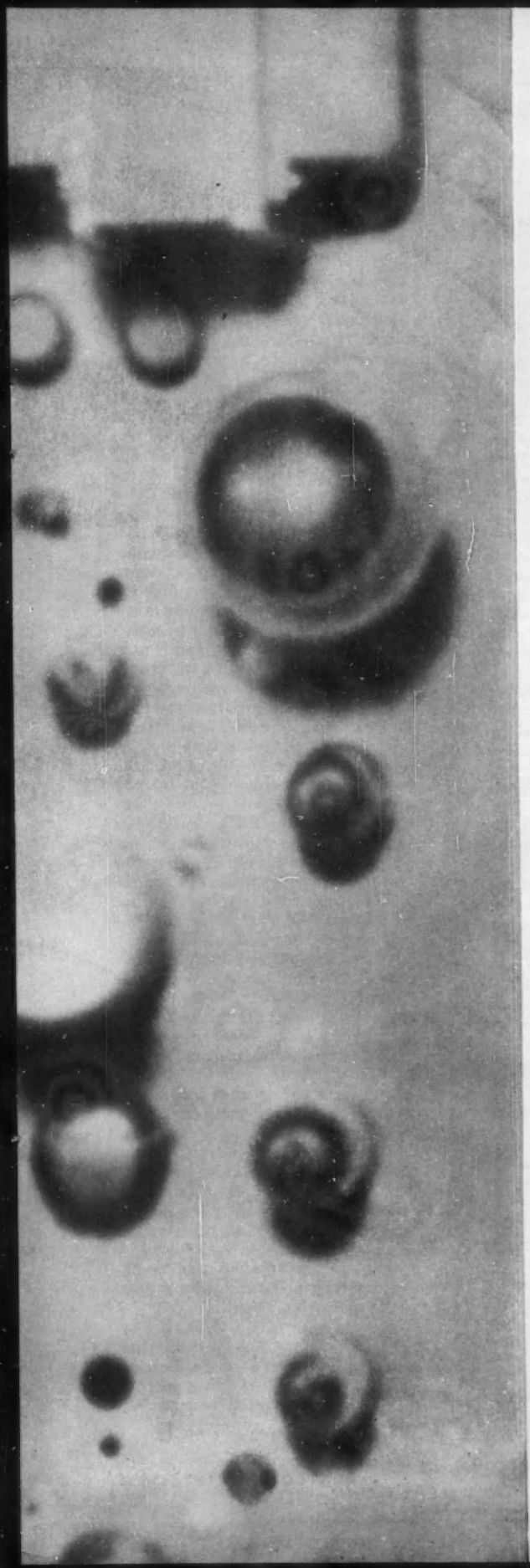

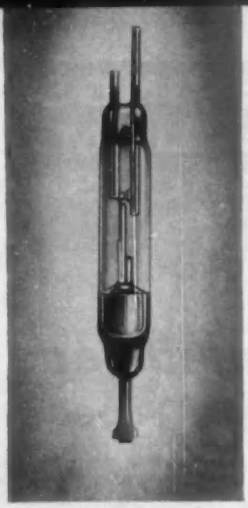

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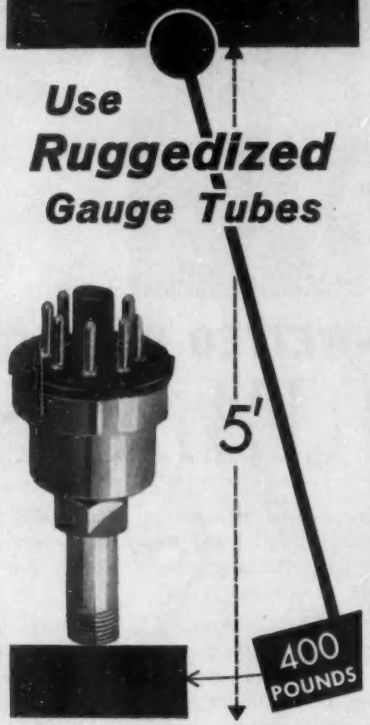

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FEEDBACK

Wrong source from source

To the Editor—

The article "VA Steps up Medical Electronic Study" (Control Engineering, May 1961, p. 32) gave credit to the wrong firm for the design and installation of "The most advanced . . ." medical electronic monitoring system. The ceiling mounted "Recor-Display" unit installed in the VA Hospital in Pittsburgh was developed by Mr. Arnold S. J. Lee of Invengineering, Inc., Belmar, New Jersey.

This fully transistorized eight-channel monitor-recorder was designed specifically to meet the operating and recovery room needs of hospitals. The recording of slow speed variables, as well as the continuous scanning of high speed variables with controlled recording on a fully synchronized oscillograph, give the unit the desired range and versatility for this type of application.

A major factor in the installation of this unit in hospitals is that the need for separate equipment rooms and full-time electronic room supervisors is eliminated, resulting in important cost savings in operating expenses, as well as initial installation costs. This feature makes the unit ideally suited for installation in existing hospitals, as well as new construction.

John Manyak
Executive Vice-President
Invengineering, Inc.

CtE obtained information on equipment suppliers from the Veteran's Administration in Washington, D. C. When the error was pointed out we checked back with our source, and found that they still didn't realize Invengineering had furnished the monitoring system. Ed.

Part II on gyro platforms

To the Editor—

In Dr. E. M. Fischel's article "Two vs Three-Gyro Guidance Platforms—II: Servo System Dynamics" (April '61, p. 122) a number of statements are unclear and do not appear to be based upon the analysis presented.

Perhaps the most important point in need of clarification is the comparison of the two platform types in terms of the error drift due to vibrational disturbances. Dr. Fischel leaves any such direct comparison out of his two tables comparing the servo system and the platform type, although he does indicate the existence of "nonlinear coupling of the single degree of freedom gyro" and "interaxis cross coupling." While Dr. Fischel gives a brief analysis of the "nonlinear coupling or rectification effect of the single degree of freedom gyro" at the end of his article, he compares this serious source of error, apparently on an equal basis, with what he calls "a cross coupling and a nonlinear mass coupling" of the two degree of freedom gyro. What Dr. Fischel fails to point out in this respect is that the platform drift due to this cross coupling, caused by the viscous damping of the fluid, is for practical systems several orders of magnitude lower in value than the platform drift due to the nonlinear coupling associated with the single degree of freedom gyro. This coupling imposes severe servo stiffness requirements on the three-gyro platform which compound the difficulties already present—the necessity to use at least a double lead network for each axis, with the attendant noise problems and need for adjustment of networks and gains.

The "nonlinear mass coupling" associated with the gimbal ring of the two degree of freedom gyro is completely negligible in practice. Dr. Fischel states that the two degree of freedom gyro is sensitive to bearing play in terms of pickoff sensitivity and proper torquer operation. Again, in practice, these considerations are of no importance with properly designed rotational pickoffs and torquers.

The author indicates that the size of platform for the two design types is "probably equal because three gyros give a better density factor for packaging." For a given size platform significantly greater volume can be allocated to each of two gyros than to each of three gyros, based upon simple geometrical as well as practical design considerations. Since the gyro angular momentum varies as the fifth power of the gyro linear dimension, the angular momentum of each of the two gyros in a two-gyro platform is significantly greater than the angular momentum achievable in each gyro of a comparable size three-gyro platform, thus resulting in lower platform drift due to gyro error torques.

H. F. Erdley
Vice President and
Director of Engineering
Guidance and Control Systems Div.
Litton Systems, Inc.

(Debate continues on page 16)

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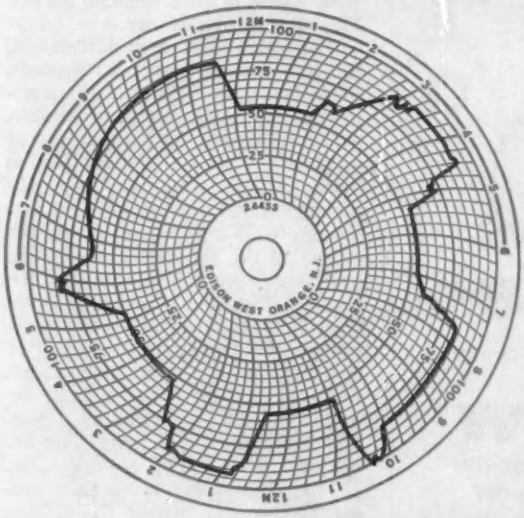

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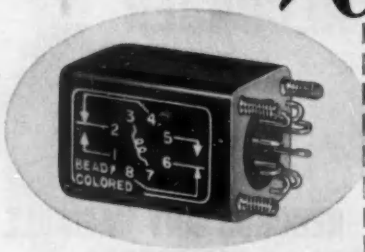

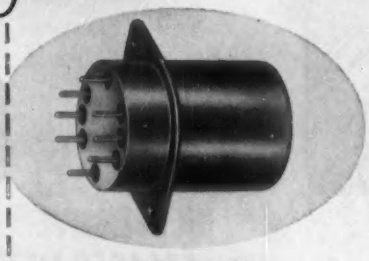

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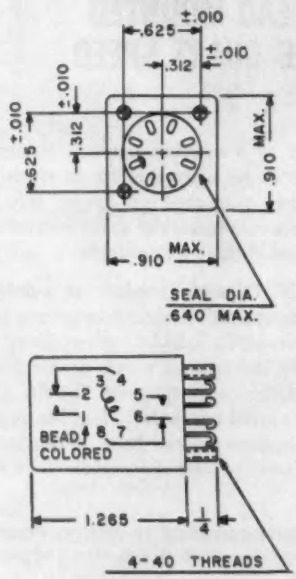

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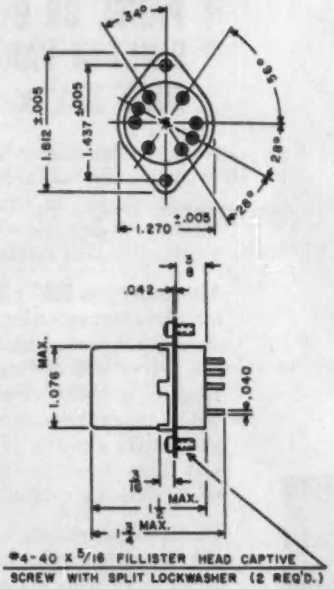

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FEEDBACK

The author answers

TO THE EDITOR—

Mr. Erdley's comment that not all my conclusions are based on the mathematical analysis is correct. A number of the points made were also based on experience in design and test, for it was only in this way that it was possible to condense material of such complex nature into a size suitable for publication.

What seems to concern Mr. Erdley most are the different coupling effects. I mentioned them in the article to point out to the non-specialist that coupling problems exist in both types of platforms, and I want to mention here that most of them cannot be considered alone. They must be multiplied by the transmissibility of the servo system in order to judge the performance of the platform.

The transmissibility is different for the two platform types and depends, for instance, on the size of the servomotor. The single degree of freedom gyro on the platform has a frequency of about 16 cps if the servo loop is open. After closing the loop, the servomotor has only to raise the frequency to 25 cps. However, the frequency of the two degree of freedom gyro loop depends entirely on the motor (and electronics); hence the motor must be many times stronger to establish an equivalent loop frequency of 25 cps. But a more powerful motor with the associated gears has a larger reflected moment of inertia and transmits many times more energy into the platform system. This is undesirable.

The engineer who wants to investigate the problem further, should look at the equation for the rectification effect for the gyro:

$$d\phi/dt = \psi d\theta/dt \qquad (19)$$

This is the drift of the gyro alone. But for the drift of the platform, which is the product of gyro drift and servo loop transmissibility, as mentioned above, the following equation must be used:

$$d\phi/dt = \omega\,(AB/2\,\Delta^2)\,X\,\Xi \qquad (20)$$

Regarding the magnitudes of this disturbing effect, we know that it can be kept small enough to be negligible by proper design. If the disturbing effects of the two-gyro platform can be made even smaller, no significant improvement will be obtained.

Coming to Mr. Erdley's last point, in which he attacks my statement that the sizes of the two different platforms are probably equal because three gyros

give a better density factor, I can only say that experience in the field has shown that the sizes are about equal.

In his argument, he stresses the well-known fact that the angular momentum H varies as the fifth power of the gyro linear dimension. Based on this, he says there results ". . . lower platform drift due to gyro error torques". That this is not always true can be seen from the following. Under vibration to which virtually every platform is subject, the mass of the gyro (which increases as the third power of the linear dimension D) plays a major role. Further, this mass appears squared in the equation for gyro drift, and gives the relationship between mass and angular momentum:

$$\text{gyro drift} \approx \frac{\text{mass}^2}{H} = \frac{D^6}{D^5} = D$$

From this it would appear that smaller gyros are preferable; but we know that this is not the whole story, and that other effects play their part in this complex matter.

E. M. Fischel
Senior Staff Engineer
Kearfott Div.
General Precision, Inc.

Westinghouse corrects us

To the Editor—

I read with considerable interest the article about the Westinghouse's new Industry Systems Dept. that starts on page 40 of your Sept. '60 issue. I was pleased that you saw fit to describe this new department.

However, there are sections of the article on which I would like to comment since I fear your readers may have gotten the wrong impression.

In the second paragraph, first page, the second sentence conveys the idea that the Industry Engineering Dept. has been replaced by the Industry Systems Dept. This is not the case. The new Industry Systems Dept. will complement the continued activities of the Industry Engineering Dept., building on the long and successful past of this group. Activities of both departments will be directed and coordinated by Dr. Patrick Conley, vice-president, Industry Engineering and Systems Dept.

In the third paragraph, page 42, you state that the Industry Systems Dept. "will pick up" work on computer control systems already sold. This is not the case. The Industry Systems Dept. will have no responsibility for jobs obtained before formation of the department. The new department will concern itself with new jobs complementing work now being done by existing departments.

Paul R. Sprowl, Manager
Industry Systems Dept.
Westinghouse Electric Corp.

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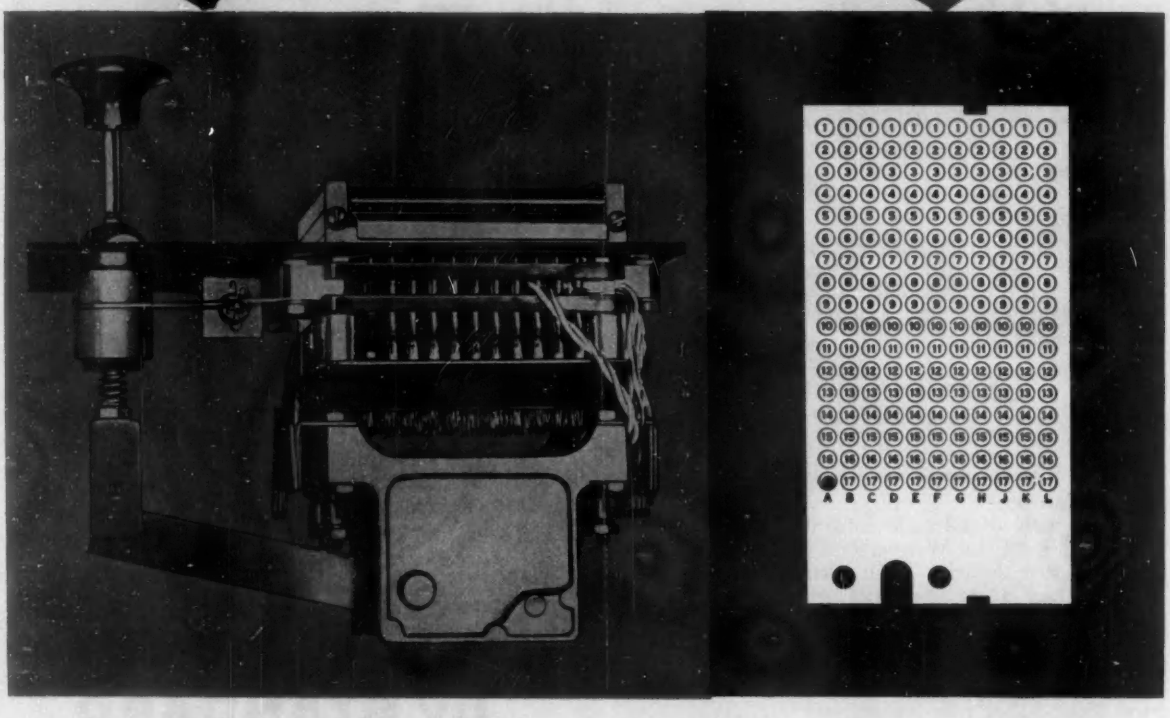

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James M. Snodgrass

what's happening under the oceans?

In a typical Hollywood movie of the 1940's the oceanographer was likely to be a wealthy dilettante who adopted this way of life because of his love for sailing, the great outdoors, and solitude. Certainly the study of oceanography has meant long periods on the water on research ships. And the oceanographer was almost a philosopher in his approach, leaning heavily on theoretical hypotheses in his study of marine biology, currents, and underwater geology.

Now a new breed of oceanographer is appearing, an engineering-oriented technical man who does his best work in a shore-based laboratory, developing new techniques for measurement, designing new instrumentation to measure under water, and devising equipment to mechanize the hoary procedures of oceanography. Typical of this new breed is James M. Snodgrass, head of special development at the Scripps Institution of Oceanography at La Jolla. Snodgrass, a psychologist by formal education, has grown into Scripps' most enthusiastic supporter of modern instrumentation.

Since he joined Scripps in 1948, he has studied the effects of high pressure on electronic components, evolving techniques for using transistorized circuitry at great depths. And he has developed deep sea telemetering cables, current meters, photometers, oxygen meters, and bathythermometers.

James Snodgrass' graduated from Oberlin College in 1931 with an AB degree and a specialization in physics and psychology. He was an assistant psychologist at the College for a couple of years and then took graduate work at the University of Pennsylvania and at Harvard. He moved into medical research at the Free Hospital for Women in Mass.

He was back at Oberlin teaching physiological acoustics when World War II broke out. In 1942 he joined Columbia University's war research division and was assigned to an antisubmarine warfare project. It was a short jump to oceanography.

After the war ended, Snodgrass spent a few years as chief engineer of the Motion Picture And Sound Div. of Dayton Acme Co. But he had been bitten by the oceanography bug and in 1948 joined Scripps as an associate marine biologist. His chief interest since then has been instrumentation.

One of the few specialists in underwater instrumentation, Snodgrass has been a spokesman for the industry's problems. Earlier this year he testified before a congressional committee urging support for oceanographic instrumentation. He told the legislators that application of such instrumentation is just beginning and adequate research facilities are needed desperately.

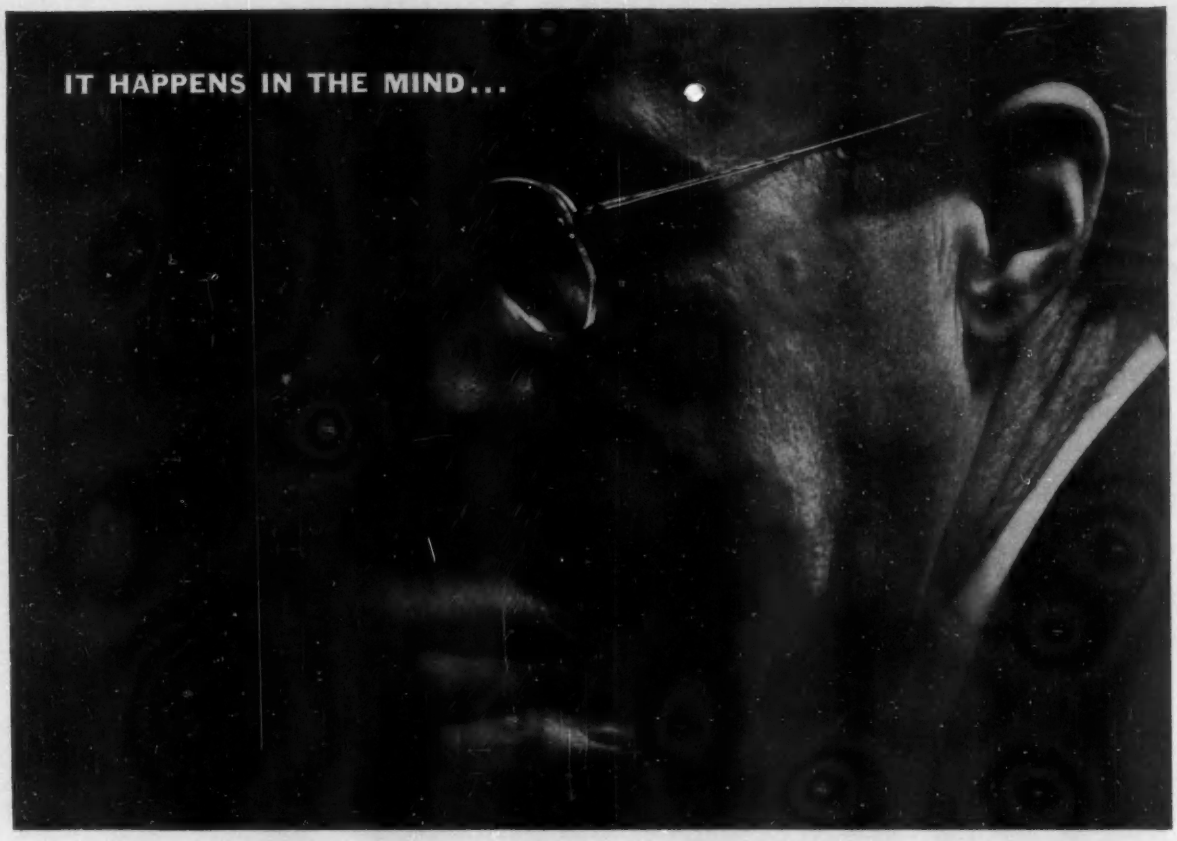
Reviewing what has and what hasn't been done with underwater instrumentation. Snodgrass credits two factors for inactivity. One is a shortage of money. In the past, oceanographic budgets have been notoriously skimpy. The second is the reluctance of oceanographers to put any faith in instrumentation. Many have had bad experiences with home-made rigs for measurement, experiences so harrowing that the researchers frequently ignored certain basic data because they considered obtaining it an impossibility.

All that is changing now. Budgets are growing (CtE, Aug. 1960, p. 61). And the exploration of space has helped reverse a lot of traditional thinking, although the return to oceanography from aerospace research has been disappointing. The problems have turned out to be too different.

One problem he feels needs urgent attention is the development of new transducers and sensors. The need is broad. At any instrumented buoy as many as 50 parameters may have to be measured, including temperature at different depths, currents, water transparency, and salinity.

At Scripps, Snodgrass' instrumentation interests are broad, too. He is concerned with getting data out of the ocean about biological, physical, or chemical phenomena to answer the question, "What's happening under the oceans?

At Bell Telephone Laboratories, mathematician Sidney Darlington has contributed notably in developing the art of circuit analysis.



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Newsbreaks In Control

Adaptive Controls for New Plotter

Wichita, Kans.—A new plotter that will verify numerical control tapes by drawing the part to be fabricated will have an adaptive control system. The radical new device is being purchased by the Air Force for the Wichita installation of Boeing Airplane Co. The plotter is being made by Gerber Scientific and the unusual control system by Bendix System Research Laboratories. Delivery expected about July 1962.

Liquid Memory

Palo Alto—Self organizing memory device called ADALINE (Adaptive Linear Classification Machine) has been built by Dr. Bernard Widrow at Stanford Research Institute. Its chief component is "memistor", an electrochemical cell less than an inch in length. Resistivity of the cell determines whether a bit of information is stored or not. Resistivity is varied by the plating of copper on a glass rod which has been coated with tin oxide. Stanford has agreement with IBM to tie ADALINE to an IBM 1620 computer.

British Atlas Bids for Computer Market

New York—New giant computer called Atlas will be marketed by Britain's Ferranti Ltd. in bid for a big piece of the world computer markets. Atlas, costing $6,000,000, can perform a million commands per second. First production unit is being installed at Manchester University which helped design the big data processor.

CRT Warnings in British Cockpits

Farnborough, England—One of the most interesting exhibits at the annual Air Show here last month was an automated cockpit warning device that flashed urgent messages to the pilot on the face of a cathode ray tube. The device was designed by Rank Cintel. A fault condition triggers a central character generator which spells out the trouble for the pilot, writing it on the face of the tube.

Machine Tool Notes

New York—Two events of importance to machine tool control makers are scheduled to take place in October. In Bar Harbor, Me., the Federal Court hearing the Bullard-General Electric numerical control patent suit (CtE, Sept. '60, p. 54) is scheduled to render a decision. At Wright Patterson Air Force Base, the Air Materiel Command will announce successful control bidders who will replace the continuous contouring systems originally supplied by Cincinnati Milling Machine Co.

HEAT, SUN, and STARS To Point Satellite Payloads

Vehicle orientation is evolving as the most ticklish aspect of control of satellites in the projects planned for the next few years. Spacemen are borrowing both old and new sensing and actuation techniques. And component reliability is still a bottleneck.

WASHINGTON—Standardized black box controls for space vehicles. With them a project engineer could put together a system to control any space project whether it be an orbiting weather satellite or a lunar probe.

That was the concept NASA's advanced controls group had about four years ago, right after the space age was born. NASA has since had to junk the idea. The space agency discovered that control requirements for different types of projects varied so much that a standard module concept was not practical.

During the past four years, the control problem in aerospace has changed drastically. Right after the first satellites were launched, the big problem was how to put a satellite in the precise orbit required for a mission. Now spacemen can put a satellite pretty much into the orbit they want and future improvements are likely to produce only a slight accuracy edge.

But the big problem today depends on the mission. In a communication satellite, for example, it is keeping the satellite in the same orbit for periods in excess of five years while the space orbiter is continually pushed towards the earth by sun pressure (CtE, Feb. '61, p. 33). In another type of vehicle, it is maintaining a platform in a precise attitude so that another vehicle can be launched into space, or scientific data can be collected.

• **Billion dollar study**—The U. S. has laid out a series of experiments that will cost billions of dollars over the next 10 years. And the program has introduced some new control problems. Typical types of projects:

- satellites that will always point to the earth to send back such data as cloud cover for weather forecasting and military intelligence, including photographs of hostile installations and infrared warnings of enemy missile firings.
- satellites in synchronous orbits so they appear to remain over one fixed point on earth.
- orbiting observatories to study celestial bodies and to map radiation effects around the earth.
- satellites that rendezvous in space for scientific and military applications.
- satellite launching platforms that can send probes deep into space.

I. Attitude Control

Attitude control has emerged as the number one problem in a lot of space projects. Most satellites launched to date have been spin-stabilized—spun like a bullet leaving a gun to maintain stability—or allowed to tumble end over end. This worked as long as the main objective was just putting a satellite into orbit. But tumbling or spinning is not satisfactory for satellites that must point in one direction all the time, for example, at the earth to relay cloud coverage information or at the sun to generate power to operate instrument payloads.

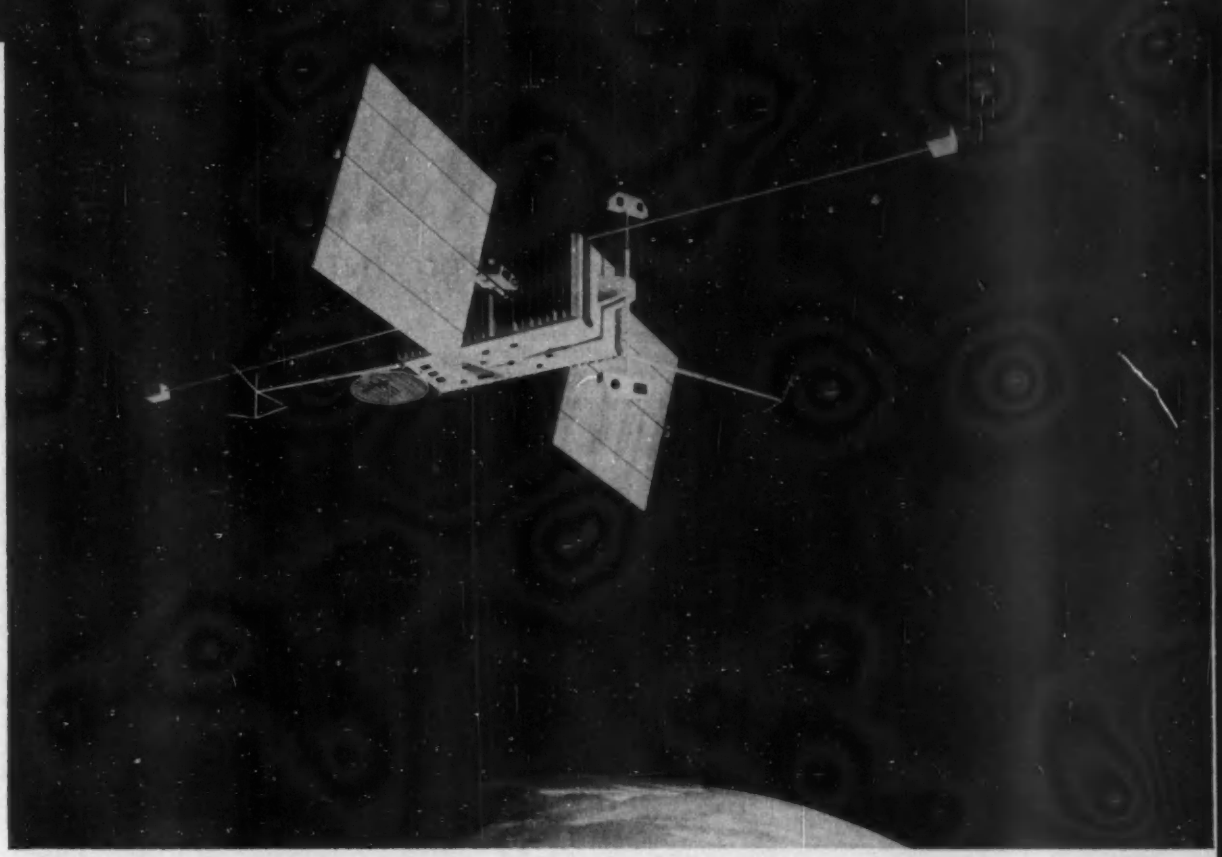
To exert such control requires sensing devices that can determine when the desired orbital condition has been reached and then some form of actuator to exert a correction if one be needed.

• **Heat, sun and stars**—At least half a dozen different techniques lend themselves to sensing for attitude control. And all of these have been proposed for one project or another depending on the accuracy of positioning demanded. They include infrared sensing, solar photo cells to align with the sun, star trackers, and inertial systems that rely on rate gyros.

Reliability has been the roughest dilemma. Engineers are hard pressed to test satellite control systems under realistic conditions that duplicate the environment of outer space. The most difficult requirement: running a piece of electromechanical equipment in almost perfect vacuum. Facilities with such vacuum capabilities are rare, though many companies in the aerospace field have started building huge vacuum test chambers.

What engineers are trying to do right now is find a reliable approach to attitude control, one they can depend on with some degree of assurance. Infrared has scored the best record to date. It has been used to determine when the cameras were pointing at earth in the Tiros weather satellites, for orientation in the Mercury man-in-space capsule and will provide attitude control in the Nimbus meteorological satellite that is to be launched soon.

Both solar cells and star trackers rely on semiconductor junctions. But no one device can follow both the



Orbiting Geophysical Observatory

sun and a star. If it can handle the bright intense radiation from the sun, the device is likely to be insensitive to the low light levels from stars; and, if it can detect stars, such as the semiconductor star tracker developed by IBM with a semiconductor and an electrolyte solution, sunlight will blind it.

• **Obstacles** – Component performance and reliability are slowing rapid advances in aerospace attitude control systems. For example, many engineers would like to use an inertial system for attitude control. They'd like to reduce the dependence on semiconductor devices whose performance can be affected by the nuclear radiations of outer space. But today's accelerometers are far from accurate enough. A NASA control engineer says they have a sensitivity of 10^{-6}; what's needed for attitude control is sensitivity of at least 10^{-10}.

With rotating components such as servomotors, synchros, and electrical actuators, lubrication in the vacuum environment is still a headache. The lubricants vaporize. And windings have to be carefully designed because coils that operate reliably on the ground burn out in the vacuum of space because of improper cooling.

• **Control actuators** – To correct satellite position, spacemen have bor-

SPACE SHOT CALENDAR

Major Space Shots Planned for Next Four Years and the Chief Control Problems

NAME	No. of Shots	Control Problem
1961		
Mercury Atlas (Man-in-Space)	5	Reliability
Orbiting Solar Observatory	1	Attitude control to position sensors
Ranger	1	Stabilization to launch space probe from satellite
Scientific Satellites	4	Instrumentation
1962		
Ranger	3	Stabilization to launch space probe from satellite
Mercury-Atlas	1	
Mariner (Venus Planetary Craft)	3	Navigation
Scientific Satellites	7	Instrumentation
Communication Satellites	2	Stabilization of orbits
Meteorological Satellites	2	Attitude control to position sensors
1963		
Orbiting Geophysical Observatory	1	Attitude control to position sensors
Communications Satellites	2	Stabilization of orbits
Surveyor for Moon Landings	2	Mid-course trajectory navigation
Mariner (Interplanetary)	1	Mid-course trajectory navigation
Orbiting Astronomical Observatory	1	Attitude control to position telescope and spectrometer.
Meteorological Satellites	2	Attitude control to position sensors
1964		
Polar Orbiting Geophysical Observatory	1	Attitude control to position sensors
Mariner	3	Mid-course trajectory navigation
Communication Satellites	2	Stabilization of orbit
Meteorological Satellites	2	Attitude control to position sensors
Surveyor	2	Mid-course trajectory navigation

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SPECIFICATIONS

CONTACTS:

Arrangement—dpdt, double break, double make. Other arrangements and sequences.

Load—25 amp resistive, 120 or 240 V a-c
25 amp ind., 120 V a-c (75% p.f.)
12½ amp ind., 240 V a-c (75% p.f.)
1 hp 120 V a-c, 2 hp 240 V a-c
25 amp resistive 28 V d-c

MOUNTING: Panel, side or socket

DIMENSIONS: 1½ x 1½ x 1⅛ inches.

U/L APPROVAL: U/L File 31481

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SATELLITE ATTITUDE CONTROL (Cont.)

rowed something old and something new. The something old is the flywheel. The Orbiting Astronomical Observatory, for example, will change its attitude in opposition to changes in momentum of a flywheel, these changes being brought about by acceleration of an electric motor.

The new is a reaction jet—and soon a computing reaction jet. Stored gas, usually nitrogen, operates the jets for a predetermined time to bring the satellite into proper attitude. Diamond Ordnance Fuze Laboratory's fluid amplifier units (CtE, May, '60, p. 26) offer the potential of a jet which can calculate its duration of discharge or its angle of discharge to bring about proper attitude control—all in one unit with no moving parts.

II. Bellwether Controls

During the next three years, three satellite experiments will successively advance the state of the art in attitude controls. Although there will be many other satellites lofted into orbit (see table) these three will mark control milestones. They are the polar orbiting Nimbus meteorological satellite, the Orbiting Geophysical Observatory (OGO), and the Orbiting Astronomical Observatory (OAO).

• **Jack be Nimbus** – The Nimbus satellite, to be launched later this year, is a follow-on version of the Tiros series. Weighing 650 lbs., it is to be oriented so that its cloud photographing cameras always point towards the earth and its cloud cover.

Control specifications dictate that the longitudinal axis vary not more than plus or minus one degree. A second requirement is that the satellite be positioned within one degree of the plane of the orbit to allow maximum scanning by infrared devices. Finally, the solar cells that will power Nimbus's instrument load have to be kept pointing at the sun.

Nimbus will rely on a variety of sensor systems. Infrared devices will keep the cameras pointing at the earth by locating the earth's horizons. Solar sensors will align the vehicle so the solar cells can "see" the sun at all times. And finally a rate gyro will determine the orbital plane attitude.

To make corrections, the weather satellite will also use a combination of devices. Six nitrogen fueled reaction jets, two mounted about each orthogonal axis, will stabilize the course. Three fly wheels, also mounted at right angles to each other, generate proportional control.

• **Geophysical survey** – Although Nimbus will be continually changing its attitude so that its cameras can photograph the earth endlessly, it always aims at the same target. The Orbiting Geophysical Observatory adds the requirement of pointing the instrument payload in different directions at different targets (the photo on page 23 shows how the OGO will look as it cruises through space).

Specifications call for the payload to be pointed in two directions with an accuracy of 2 deg.

• **OAO Most Complex**–The most complex of these milestone projects will be the Orbiting Astronomical Observatory, a $30 million vehicle to be launched in 1964. Major job of the control system is to point a telescope and a spectrograph with startling accuracy. Controls contractor General Electric (working with the prime contractor which is the Grumman Aircraft Corp.) is shooting for an accuracy of $\frac{1}{10}$ sec of arc—compared to about $\frac{1}{10}$ deg the same contractor expects to provide in Nimbus. Actually, the satellite's control system will have a pointing accuracy of one minute of arc and corrections from the ground will bring about the final accuracy.

In OAO, accuracy is critical. One of the key pieces of instrumentation is a spectrograph which will work if it is pointed correctly but which will not work if its direction is off.

Sensors of OAO are star trackers which will be aimed at selected stellar bodies by ground control. For star acquisition, the initial stabilization and orientation mode is accomplished in 48 min of sunlight.

• **Advice from the ground**–For the immediate future, NASA is not relying completely on self-contained control systems for any of its sophisticated satellites or deep space probes. Instead, data on inflight performance will be collected so that correction commands can be computed on the ground and then relayed to the satellite. In this way the need for airborne computation of sophisticated levels is reduced. And NASA sees no problem getting commands to the spacecraft.

—Seth Payne
McGraw-Hill News

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CIRCLE 25 ON READER SERVICE CARD 25

AVAILABLE TEACHING MACHINE PROGRAMS

U. S. Industries	Encyclopedia Britannica Films	TMI Grolier	Basic Systems
Mathematics			
Algebra Computer mathematics Mathematics essentials Trigonometry Slide rule fundamentals (I, II, III)	Algebra I Algebra II Plane geometry Calculus I Calculus II Trigonometry College trigonometry* Solid geometry* Analytical geometry* Intermediate calculus* Differential equations*	Arithmetic multiplication and div. Arithmetic decimals Algebra I Algebra II Statistics	Trigonometry* Plane geometry* Coordinate geometry* Probability theory* Elementary set theory*
Physics			
The oscilloscope Electronics	None	DC electricity	Measurement* Conversion of units* Mechanics* Electricity and Magnetism*
Biology			
None	None	None	The skin* The skeletal system* Mitosis*
Chemistry			
None	None	None	Atomic structure* Descriptive chemistry* Electronegativity* Covalent bonds* Decomposition* Dispersion and solutions* Oxidation-reduction reactions* Equilibria*
Languages			
None	None	Russian German Spanish Hebrew	None
Others			
Bridge for beginners	Management science*	English spelling English punctuation Music fundamentals	None

*Available after January 1, 1962.

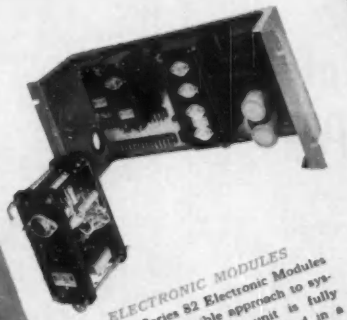
AUTOMATIC TEACHING MACHINES: Programs Start to Appear

NEW YORK—As students throughout the U.S. start back to school this fall, not many of them will face automatic teaching machines (CtE, June '60, p. 20) instead of human instructors. Educator reluctance to accept the machines and their principles of reinforced learning has itself been reinforced by a continued shortage of good programs for the machines. But, as the table above shows, programs are starting to appear.

At an American Management Association seminar last month almost 600 representatives of school systems, universities and colleges, and industry gathered to take a look at what's available in machines and programs. The turnout proved there is considerable curiosity about the new method of teaching: the AMA had expected only 150 attendees when it scheduled the meeting. After looking over a variety of machines, most of the visitors concentrated on where to find something to put into the machines–tested programs on specific subjects.

• **Tyros springing up**–New companies are springing up rapidly to fill the program vacuum. One with the most ambitious plans, 21 programs to be available around January 1962, is Basic Systems, Inc., which celebrated its first anniversary only last month. Another, General Education, Inc., was set up just last May to custom write programs for industrial, military and academic customers. Koncepto-Graph Corp., a third relative newcomer, is

electrohydraulic components for industrial servosystems



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. . . prices range from $10 to $40 per frame and a typical program has 1,000 frames . . .

starting to prepare segments of programs that have been written in educator's workshops. Its president, R. H. Hartjen, thinks that pieces of programs have a better chance of winning educator acceptance at this time than a program for a whole course.

The three big names in automatic teaching machine programs, all of whom have chalked up sizable sales of programmed materials, are U. S. Industries, Encyclopedia Britannica Films, and the Grolier Society.

Most of the USI.'s program sales can be traced to TutorText, the scrambled book programs that USI writes and Doubleday, Inc. publishes. Almost 100,000 copies of the first five titles have been sold. USI. is now writing four more books for the TutorText series and has started preparing programs for industrial users. It has underway preparation of custom programs for specific customers to teach subjects that range from principles of heating for plumbing equipment salesmen to the fundamentals of insurance for life insurance salesmen.

Encyclopedia Britannica Films has moved its program writing center from Hollins College, Va., to Stanford University in Palo Alto. As the table shows, the company has 6 programs available, will have five more advanced mathematics programs and a management science program ready by January 1962.

The Grolier Society is marketing the programs and teaching machine made by Teaching Machines, Inc. There are 16 programs now available and more coming.

• **High cost of learning**—The big problem in program preparation remains the high cost. Dr. Francis Mechner, technical director of Basic Systems, has figured that programmed materials take 20 times as many manhours to prepare as conventional teaching texts. Writing calls for a team made up of subject specialists, psychologists, and writers.

Program prices range from $10 to $40 per frame (or page) of material. In most automatic teaching machines, a student uses about 100 frames per hour. Unless the cost can be spread over many students, the price of a typical program, which averages over 1,000 frames, becomes prohibitive.

Another problem plaguing program writers is how to publish the pro-

grams and make them available. Should they be published as textbooks? For what machines should they be designed? Should they be printed on rolls of paper, in sheets, or on microfilm? Nobody is yet sure of the answer.

USI. has, of course, published its programs as TutorTexts and on microfilm for use in USI's electromechanical Autotutor. Basic Systems has an agreement with Meredith Publishing Co. and all its programs will first appear as programmed textbooks. Encyclopedia Britannica publishes its programs in loose-leaf book form.

• **New machines too**—Although much of the interest was in programs, there were some new machines on display at the AMA session too. Thompson Ramo Wooldridge showed off its Mentor, a prototype of an electronic trainer, for the first time. Built with many of the logic modules designed for the RW-300 process control computer, Mentor combines electronic logic with motion picture or slide-projector and a tape recorder. A student hears and sees explanations and then pushes buttons to answer the questions that check his progress.

Eastman Kodak's Recordak Div. showed a machine that runs on a microfilm program that is held in a narrow oblong plastic card. Kodak has no interest in writing programs but is willing to reproduce any program on microfilm.

• **Industrial dent**—Many machine manufacturers feel that the industrial market is more receptive to automatic teaching units than academic users.

One of the most promising industrial applications appears to be the data processing business. Every computer manufacturer maintains a stable of instructors who travel around the country to train customers and potential customers. Each maker offers several courses and automatic teaching might well be usable for most of them.

IBM has experimented with a programmed workbook to teach basic facts about its 7070 computer to customer engineers. As a result, the big computer company thinks proper use of automatic teaching programs might reduce its training bill by 10 percent.

Systems Development Corp., which has been experimenting with computers for teaching—using a Bendix G-15 and considering a Philco 2000—has trained almost 1,000 potential programmers with scrambled textbooks on computer number systems.

Despite the apparent problems and the continued inertia of educators, everybody in the teaching machine business is enthusiastically optimistic about the future. They agree to a man the big market could happen at any time. It might even be tomorrow.

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This little strain gage accelerometer (1 cubic inch, 3 ounces) tells how missiles and electronic equipment stand up in transit. Little as it is, it happens to be better than all comparable accelerometers. Ie., lowest cross axis response; smallest damping change with temperature; highest resonant frequency; operable temperature range from −70°F to 300°F. And it's just as durable as that one over there on the left. Need some? Call your nearest CEC office or write for Bulletin CEC 4202-X13.

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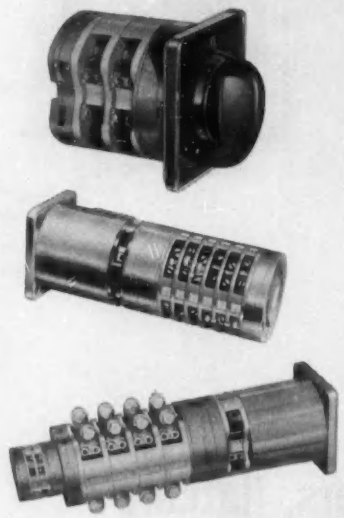

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Fiber Optics Promises Radical New Display Gear

Prototypes of some startling new test and display equipment were shown at the west coast's annual electronics show. Production still may be a problem.

SAN FRANCISCO—From the welter of over 850 exhibits, glamourizing new electronic equipment at this year's annual Western Electronics Show and Convention (WESCON), probably the most exciting development wasn't new at all. Fiber optics is moving from a laboratory curiosity to an important design technique for electronic test and display equipment.

Since 1870, physicists have known that light can be conducted along a curved path. Advertising men have built eye-catching displays with light carried around corners by plastic tubes. In the last six months, however, engineers have succeeded in building some unique display equipment with bundles of very thin glass fibers, usually coated with a layer of glass of a different kind. These bundles can transport an optical image over a tortuous path and can transform it.

WESCON was the first show to host a concentration of fiber optic devices. Shown for the first time was an optical fiber Charactron tube, built by General Dynamics/Electronics. Cathode ray tubes with fiber optic features were also shown by DuMont Laboratories and Litton Industries. A "Fiberscope"—a bundle of fibers with a lens at each end of the bundle—was displayed by American Optics.

• **Line-at-a-time printer** – General Dynamics has put a fiber optic faceplate on a Charactron tube. The fibers, about ½ in. long, transmit the image formed on the light-emitting phosphor by the electron beam, through the glass envelope of the cathode ray tube. Direct contact printing of the image is possible if a piece of sensitized paper is placed against the end of the bundle outside the tube envelope.

The big advantage of direct printing is brighter images and better resolution. Normal faceplate glass on a cathode ray tube reflects some of the light and scatters some more of it so the end product loses brightness. The same advantages apply to fiber optic faceplates on simple cathode ray tubes.

In the General Dynamics design, the fiber optic faceplate is a strip that can print one line of computer data at a time. The strip is a full page width —8½ in.—and ½ in. high.

The American Optical Co. display was a crowd pleaser that was designed to show the capabilities of fiber optics rather than a particular device. For example, a visitor could put one end of the Fiberscope in his own ear and view the aural canal.

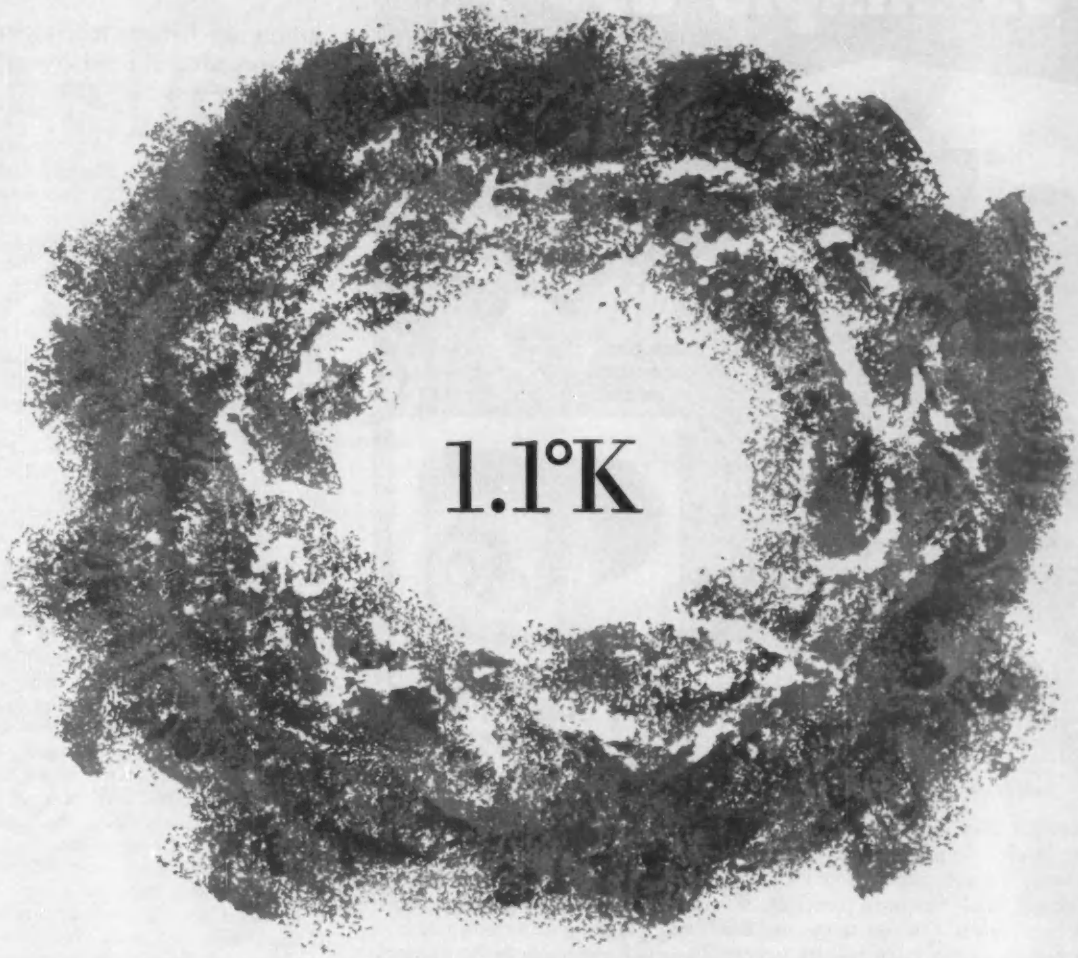
• **Selling problem**—Production bottlenecks may slow the commercial availability of these fiber optic devices. In the manufacture of the cathode ray tubes, a vacuum seal has to be made around each fiber as it passes through the tube's glass envelope. Since each fiber may be as small as 15 microns in diameter, and there are thousands of fibers in a faceplate, sealing in the vacuum is not easy.

General Dynamics has built 10 laboratory models and has had sample tubes in operation for about six months. Price: about $5,000 apiece.

• **Other displays**—a lot of manufacturers took advantage of the expected large turnout (the expected attendance was 35,000, but just under 30,000 visitors registered) to introduce new products that ranged from complete systems to solid state components. Among those of most interest in control engineering:

▶ Iterative analog computer (differential analyzer) whose components have an accuracy of 0.01 percent and whose amplifiers have a bandwidth of 1 megacycle. Supplier: System Donner Corp.

▶ Frequency sensitive resonant reed relay has no electrical contacts. The reed acts as a shutter between a light source and a photosensor. Special combinations can be developed to perform logic functions. Supplier: JBT Instruments, Inc.



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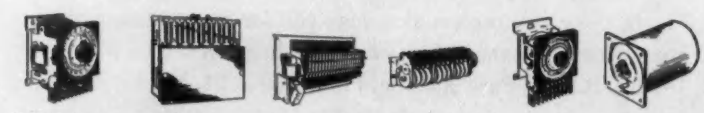

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Britain Revives the Airborne Computer

British are betting that commercial aircraft will need computers for navigation by 1970.

LONDON—

Britain's General Electric Co. is flight testing the U.K.'s first airborne digital computer designed for aircraft. Although elsewhere, enthusiasm for such devices has waned with the rise of missilery and the decline of military aircraft, the British envision a big potential for the transistorized machine in aviation—military and civilian.

For one thing, Britain is committed to manned military aircraft as its main aerospace weapon until at least 1970, contrary to the missile-oriented plans of the U.S. That's why the Royal Air Force has encouraged GEC. In fact, The Royal Aircraft Establishment at Farnborough cooperated in the development. And then Britain engineers are betting on a civilian aircraft market for such a device by 1970.

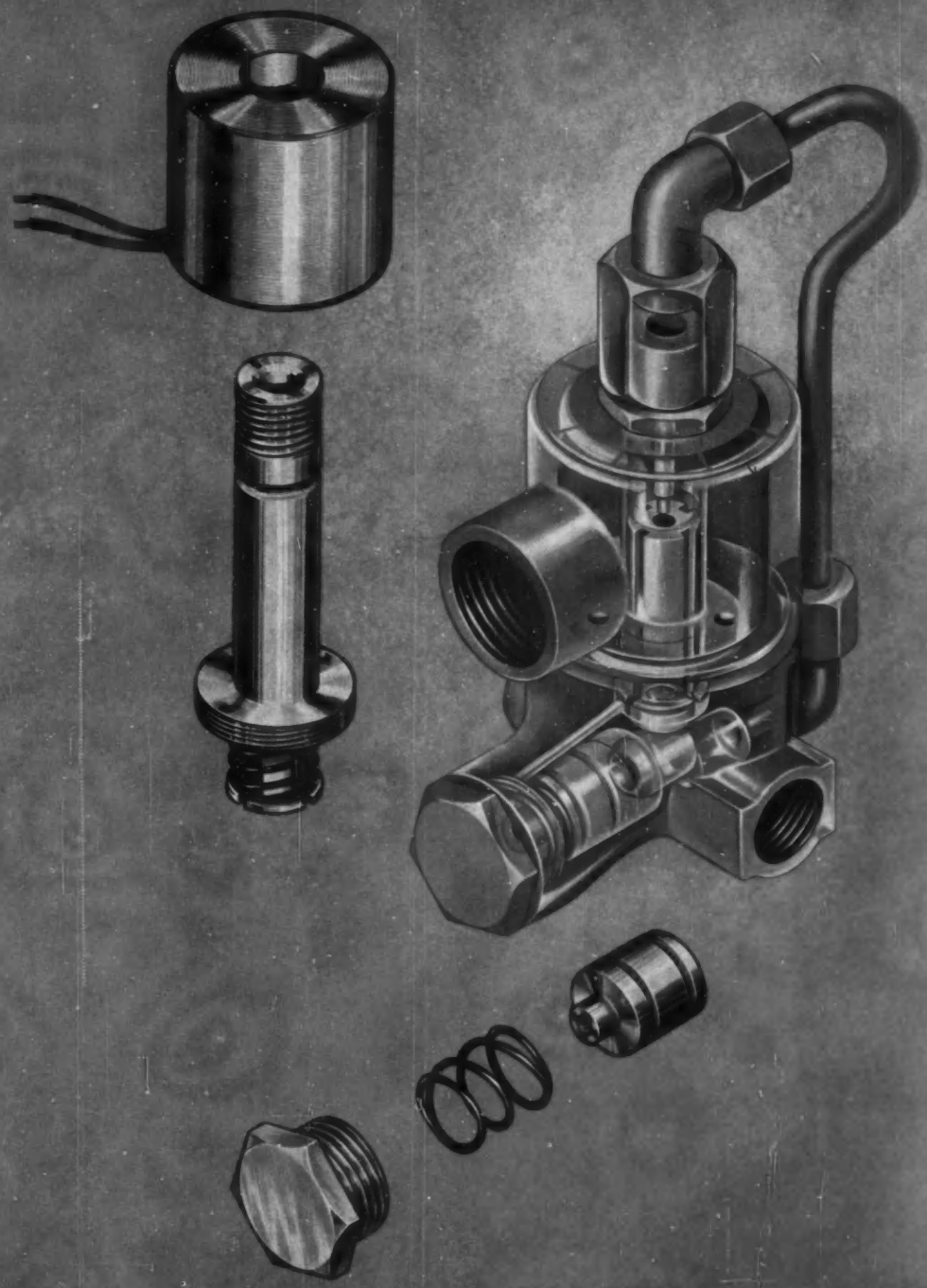
GEC calls its new computer Dexan. It is somewhat similar in design to Verdan, the airborne computer North American Aviation built in the U.S. The British company claims its machine is somewhat faster than Verdan since it has an addition speed of 165 microsec and a multiplication time of 12 millisec. But performances are not comparable because most operating characteristics of both are secret.

Dexan is actually a hybrid machine. Computation is carried out both in the mode of digital differential analyzer which calculates increments in steps, and a general purpose machine operating on whole numbers. Its core memory has a capacity of 1,024 20-bit words. Production version should occupy a cubic foot of space and weigh about 50 lb.

In first flight tests, the computer has served as a navigation center determining aircraft position from doppler radar and gyro inputs. Accuracy of the computer is said to be "adequate" and "greater than that of the inputs".

Most of the interest in Dexan today is military; civil interest is almost nil. But GEC feels strongly that by 1970, navigational requirements for commercial aircraft will be so complex that some form of computer will be required. When the time comes, GEC hopes to be ready for the market.

(For business news turn to p. 148)



SKINNER 2-way Solenoid Valves

for high flow, high pressure applications

Here's how Skinner two-way valve design provides long lasting, trouble-free operation

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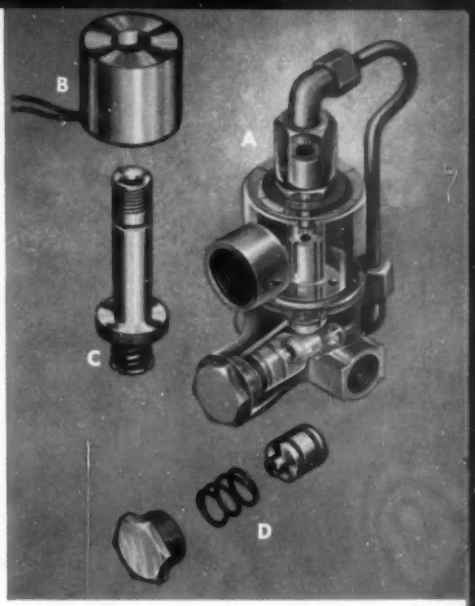
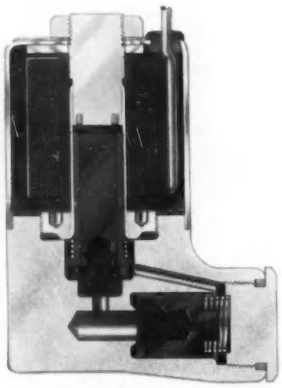
- **Stainless steel internal parts resist corrosion**
- **Forged naval brass body**
- **Famous Skinner V5 solenoid operator**
- **Well rounded main orifice and pilot seats**



A—Transparent view of normally open 2-way R type valve with piped pilot exhaust return
B—Coil C—Sleeve, plunger and spring assembly
D—Piston assembly with soft synthetic insert



NORMALLY CLOSED TYPE R2

When you have high-flow control problems at standard or high pressures the new Skinner two-way R series valves may be the answer. These pilot-operated solenoid valves are designed for use with air, oil, water, inert gases and other common media at operating pressure differentials of 5 up to 1250 PSI. They may be used for all types of control applications, such as: in high-pressure lifting, commercial laundry equipment, machinery, machine tooling, spraying, etc.

Skinner R series two-way valves have forged naval brass bodies to provide a dense metal structure and use a foolproof stainless steel piston with soft synthetic insert to open and seal the main orifice. Types are available normally open or normally closed, in standard and explosion-proof construction.

To make installation easy for every application, a wide choice of electrical housing options is available. These include JIC, AN connector, automotive terminals, etc. All housings can be rotated 360°. Manual override is also offered to permit manual opening of normally closed valves, or closing of normally open valves, in emergency.

Skinner R series valves may be used with all common voltages and frequencies and there are several coil types such as: varnished, molded waterproof, tropicalized and high temperature for specific applications.

The R series, illustrated here, is just one in a complete range of 2-, 3- and 4-way Skinner solenoid valves.

TWO-WAY R SERIES SPECIFICATIONS

Types	R2 XR2	R2H XR2H	R2H6	RP1 XRP1
Position	Normally closed	Normally closed	Normally closed	Normally open
Pipe Size (NPTF Dry Seal)	¼"	¼"	¼"	¼"
Orifice Size	¼"	¼"	¼"	¼"
Cv Factor	.758	.758	.758	.758
Operating Pressure Differential (PSI) Minimum	5	5	5	5
Maximum AC Service	200	1250	—	150
Maximum DC Service	200	500	1000	150
Leakage	Bubbletight	Bubbletight	Bubbletight	Bubbletight
Temperature Range (Ambient and Media)	Minus 40°F to plus 180°F	Minus 40°F to plus 180°F	Minus 40°F to plus 180°F	Minus 40°F to plus 180°F

When you specify solenoid valves, specify Skinner. Skinner solenoid valves are distributed nationally.

For complete information, contact a Skinner Distributor listed in the Yellow Pages or write us at the address below.

SKINNER ELECTRIC VALVES

THE CREST OF QUALITY

SKINNER ELECTRIC VALVE DIVISION
SKINNER PRECISION INDUSTRIES, INC. • NEW BRITAIN, CONNECTICUT, U.S.A.

PRINTED IN U.S.A.

a major advance in Digital Control

NEW LOW COST DIGINAMICS DIGITAL TRANSDUCERS

OFFERING . . .

TRUE SYSTEM COMPATIBILITY

Each component is capable of operating individually or collectively with any digital controller or data recorder. Outputs from each component are conventional D-C level code. Optional outputs as follows: Parallel, serial (forward or backward) and sample storage.

IMPROVED RELIABILITY

Complete value readout eliminates error often present with incremental readout. Direct digital transduction and transmission of relatively high voltage signals require fewer piece parts. Error buildup is reduced by eliminating additive conventional analog tolerances. Output signals are capable of transmission over long lines.

COST-SAVING SIMPLIFICATION

The usual millivolt switching, operational D-C amplifiers, voltage to frequency converters, frequency counters and voltage to digital converter equipments are no longer necessary.

A Pressure to Digital Transducer — Models 2012-2030
Vacuum, absolute, gauge and differential pressure ranges
Complete value digital output, parallel or serial

B Temperature to Digital Transducer — Models 3012-3030
Direct to 200°F. Remote to 2200°F.
Complete value digital output, parallel or serial

C Shaft Position to Digital Transducer — Model 4012
Forward or Backward rotation
Divides one revolution into 1024 parts
Load torque less than 0.1 gram-centimeters
Complete value digital output, parallel or serial

D Parallel to Serial Converter (Serializer) — Model 5012
Convert any number of parallel bits to serial data — most significant bit first or least significant bit first
Conversion from reflected binary to binary code if desired
Optional sample storage, parallel or serial output

E Sampling Multiplexer — Model 6012
Completely solid state
Basic unit accepts 16 inputs
Additional inputs may be added in multiples of 16
Input and output levels adjustable

NOTE:
Units shown in this ad are ⅓ actual size.
Basic units operate over range —40°F to +158°F ambient.
Higher temperature ranges available.

Write today for specifications and prices.

DIGINAMICS CORPORATION

2525 East Franklin Ave. Dept. B Minneapolis 6, Minn.

DIGITAL INSTRUMENTATION
DIGITAL TRANSDUCERS
DIGITAL CONTROL SYSTEMS

←CIRCLE 34 ON READER SERVICE CARD

CIRCLE 35 ON READER SERVICE CARD

General Electric Makes Eddy-current-coupling Drives

And they're dependable drives. The complete line includes water-cooled and air-cooled eddy-current couplings. We call them KINATROL* drives. Ratings are from 1 to 150 horsepower, operating from standard a-c power.

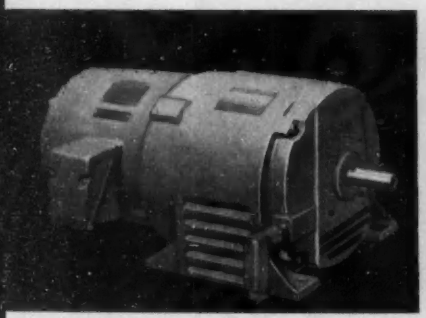
A General Electric KINATROL drive is not just another eddy-current coupling. For instance, in the water-cooled coupling, water control is packaged. You'll see much less external piping. Furthermore, the coupling is protected from flooding—and the air gaps are dry, preventing corrosion.

KINATROL couplings are compact, field proven and dependable. General Electric has had a good deal of experience in the engineering, manufacturing, and application of packaged adjustable-speed drives. And we know how important service is to a customer.

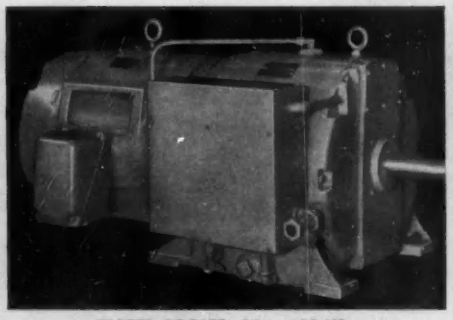
KINATROL—a good product, with the kind of service you can depend on. Please call your nearest General Electric Sales Office for further details.

*Trademark of General Electric Company

821-07



AIR COOLED, 7-1/2 to 100 HP



WATER COOLED, 25 to 150 HP

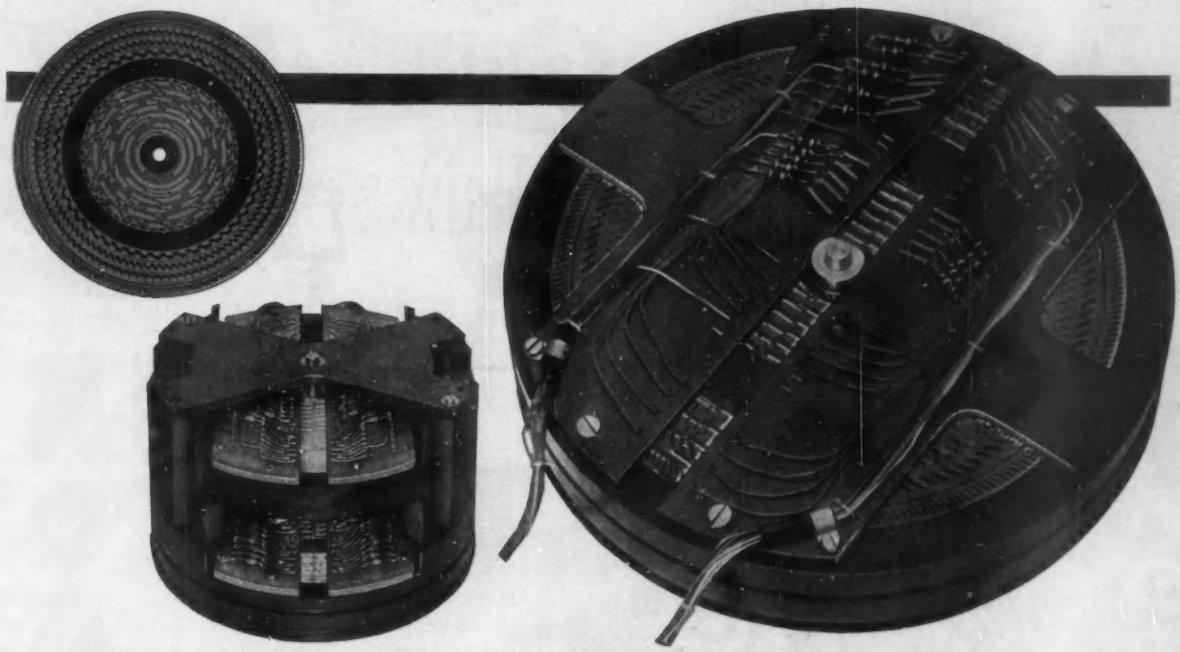
AIR COOLED, 1 to 5 HP

DIRECT CURRENT MOTOR AND GENERATOR DEPARTMENT

GENERAL ELECTRIC

ERIE, PENNSYLVANIA

CIRCLE 36 ON READER SERVICE CARD



Now Norden binary-coded decimal converters for commercial application

- **1000 count per turn**
- **self-contained logic**
- **self-selecting brushes**
- **continuous reading at high speeds**
- **several models in 4 2 2 1 code***

Norden offers a wide variety of binary-coded decimal shaft encoders for commercial applications. These encoders meet or surpass military specifications, and have patented, self-selecting V-brush logic.

Code disc patterns produce a totally unambiguous 8-4-2-1* binary decimal readout ranging from 2 to 6 decades. The units can be used for feeding high speed computers and servo systems . . . data logging, machine tool automation, test stands, flight check-out. Self-selecting V-scan increases reliability and life while saving space and reducing complexity and cost. Load carrying brushes never commutate. These are the only encoders that have provision for automatic self-checking gating devices for virtually 100% error monitoring.

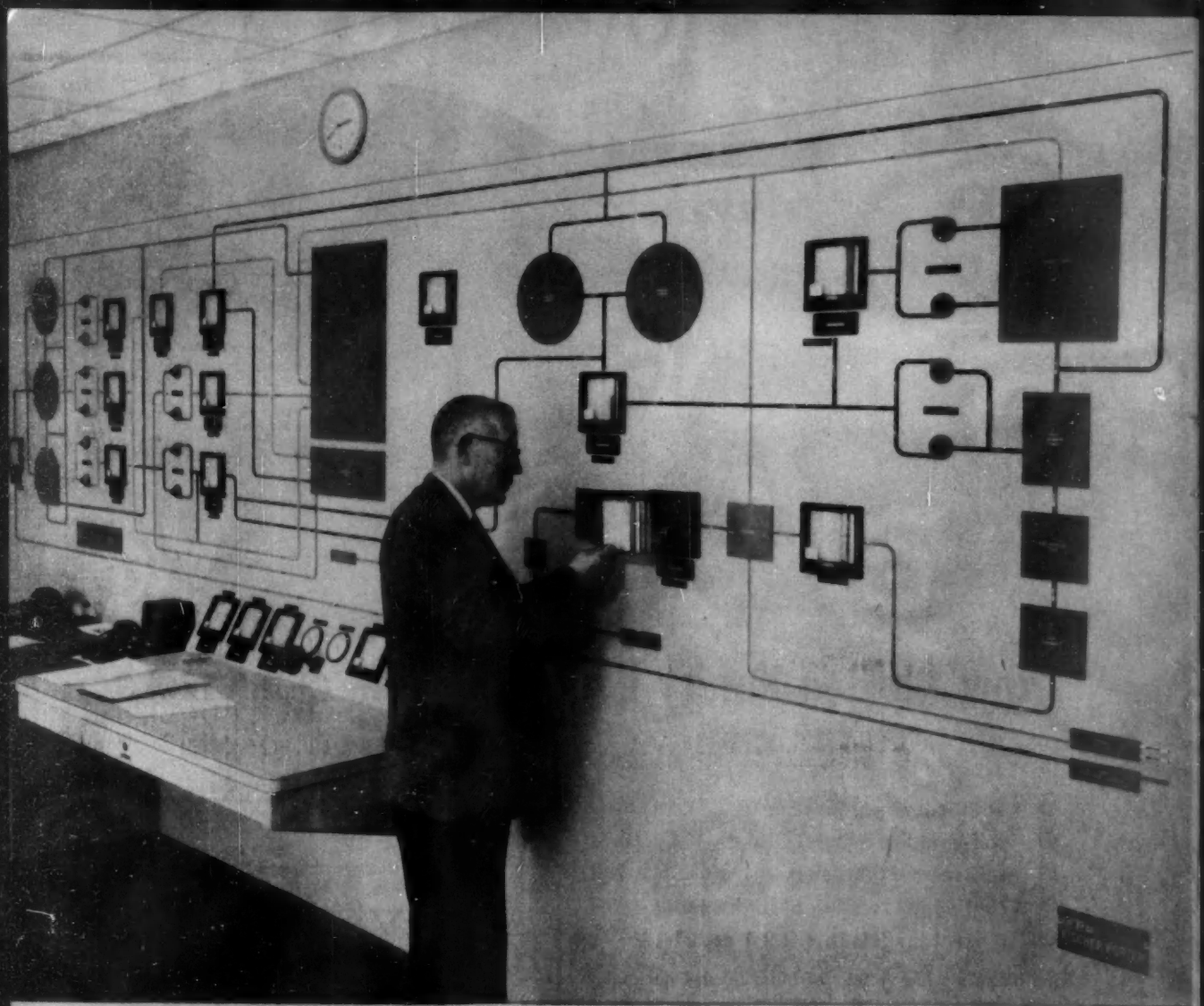
*Several models are available in *4-2-2-1 CODE* which provides a nine's complement and makes available in a single encoder an increasing numerical count for both directions of shaft rotation.

MODEL NO.	TOTAL COUNT	REVOLUTIONS FOR FULL COUNT	ACCURACY (1 part in)
ADC-ST2-BCD	10^2	1	100
ADC-3-BCD	10^3	10	1,000
ADC-4-BCD	10^4	100	10,000
ADC-5-BCD	10^5	1,000	100,000
ADC-6-BCD	10^6	10,000	1,000,000
ADC-ST3-BCD	10^3	1	1,000
ADC-5-BCD-1000	10^5	100	100,000
ADC-3-36BCD	360	3.6	360
ADC-4-36BCD	3600	36	3,600
ADC-5-36BCD	36,000	360	36,000
ADC-6-36BCD	360,000	3,600	360,000
ADC-ST3-36BCD	360	1	360
BRL-5	360,000	1	360,000
ADC-ST2-8BCD*	10^2	1	100
ADC-3-8BCD*	10^3	10	1,000
ADC-4-8BCD*	10^4	100	10,000
ADC-5-8BCD*	10^5	1,000	100,000
ADC-6-8BCD*	10^6	10,000	1,000,000
ADC-3-36BBCD*	360	3.6	360
ADC-4-36BBCD*	3,600	36	3,600
ADC-5-36BBCD*	36,000	360	36,000
ADC-6-36BBCD*	360,000	3,600	360,000

Write Norden or call TEmple 8-4471 for complete specifications

NORDEN division of UNITED AIRCRAFT CORPORATION

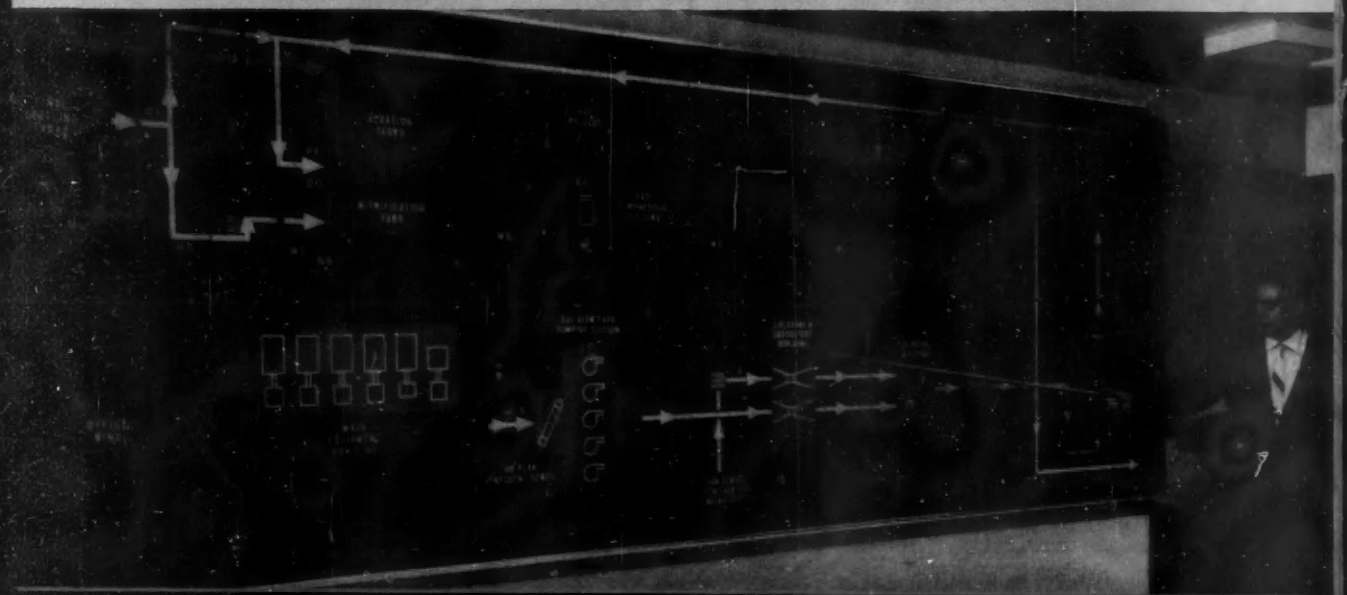
NORWALK, CONNECTICUT



"Chart Room" in the modern Pollution Control Center of the City of Toledo, Ohio.

Plant designers: Conner, Townsend & Associates, Chicago.
Instrumentation: Fischer & Porter Company, Warminster, Pa.

Lecture Room panel helps explain process. This plastic, back-lighted flow panel gives visitors a better picture of the waste treating operation. The special room can hold up to 80 people. Regularly conducted plant tours help promote good community relations.



"World's Most Glamorous Sewage Plant" Teaches a Lesson In Instrumentation

Regardless of your process, you'll get answers that will challenge your imagination

Unlikely place to look for instrument answers? Certainly not! Toledo's new Sewage Treatment Plant is so spic-and-span modern—and so precisely instrumented—that it could be a food processing plant—a refinery—or a laboratory. Throughout the system, sharp-eyed Fischer & Porter instruments monitor the 50 million gallons per day effluent flow and meticulously record all phases of the operation. And in the "Chart Room" shown at left, a graphic panel traces the entire process, while all key fluid flows are recorded and totalized on miniature F&P instruments. Operators and management alike check out the many process flows from this central control room in the compressor building.

Meet Me at the Sewage Plant Most Any Afternoon!

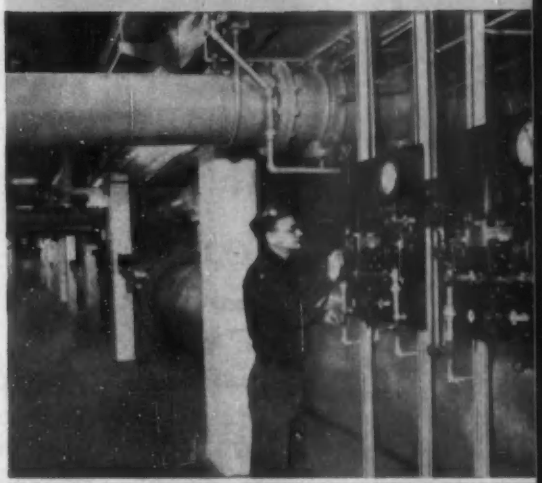
Amazing—the number of people who gather to spectate at Toledo's Sewage Plant! Engineers. Technologists. Process Men. People like yourself. An illuminated, color-coded flow panel installed in the *Lecture Room* makes it easy to understand the process. Switches on a nearby desk illuminate flow lines in different colors.

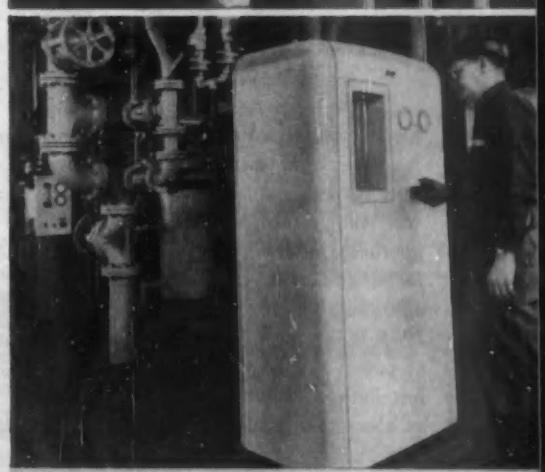
Precise Pollution Control—No Maintenance

Operators report that F&P equipment—from flow meters to O-R-P unit to chlorinators—functions perfectly, month in and month out. With only one technician riding herd on instrumentation *and* all electrical work. Negligible instrument service time makes his primary electrical job easy as rolling off a "log."

So that's the Toledo Sewage Plant story—and here's the moral: On your next control system, contact Fischer & Porter—where you get true unified responsibility from design through operation. For our over-all story in brief, write for a copy of Catalog 310. For a discussion of your specific control problem, call your nearest F&P field engineer. Fischer & Porter Company, 801 County Line Road, Warminster, Pa. In Canada: write Fischer & Porter (Canada) Ltd., 2808 Jane Street, Toronto.

In the tunnel under the tanks, where most of the various flows are measured. Each local panel contains a Fischer & Porter dp transmitter, square root-to-linear signal pneumatic relay, indicating flow gauge and meter manifold. Values of these flows are also transmitted to the central panel for recording and totalizing.





Chlorinators complete the treatment. Two F&P 6,000 pounds per day chlorinators accomplish the chlorination job in conjunction with two steam evaporators located in the top floor of the laboratory building.

FP FISCHER & PORTER COMPANY

A world-wide Instrument Company with plants in Australia, Canada, England, France, Germany, Holland, Mexico and the United States.

CIRCLE 39 ON READER SERVICE CARD

1962 1963 1964 1965 1966

All

LAMBDA

Power Supplies guaranteed for 5 years

Every Lambda power supply carries a written guarantee that it will perform to specifications for five full years. You can install power supplies now with complete assurance that they will still perform to design standards in 1966. *Lambda's guarantee, which covers workmanship and materials (except for tubes and fuses), has been in effect on all power supplies sold since 1953.* It is your strongest assurance of power supply performance in installations where dependability is an absolute necessity for round-the-clock, heavy-duty service.

SEND FOR NEW LAMBDA CATALOG 61

ALL-TRANSISTORIZED
LA SERIES

Nine Models Available
Voltages up to 330 VDC—Currents up to 20 Amp
Convection Cooled—Short Circuit Proof

LAMBDA ELECTRONICS CORP.

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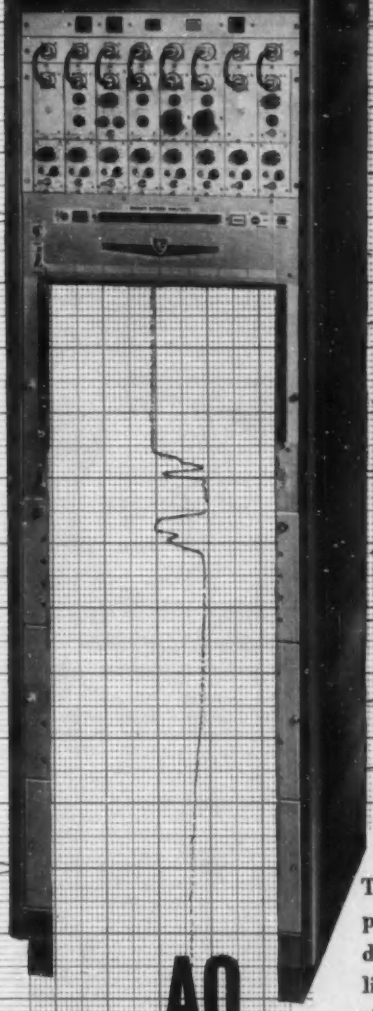
CIRCLE 40 ON READER SERVICE CARD



AO Trace-master provides twice the definition

The unique direct-carbon-transfer writing method produces a trace from 2 to 3 times finer than any other direct-writing technique. This allows twice as many lines per millimeter . . . twice the definition! Resolution is unsurpassed . . . each line is uniform in width and contrast, revealing the most minute variations in the phenomena measured with utmost fidelity. This writing technique combined with the advanced pen-motor design produces a wider frequency response at larger amplitudes. Continuous recording of data can be displayed simultaneously on 8 channels . . . up to 8 independent event markers can be added. Ten chart speeds — 0.1 to 500 mm/sec — provide a 5000:1 chart speed ratio.

The AO Tracemaster has become the new standard of performance for these and many other reasons . . . write now for the full story!

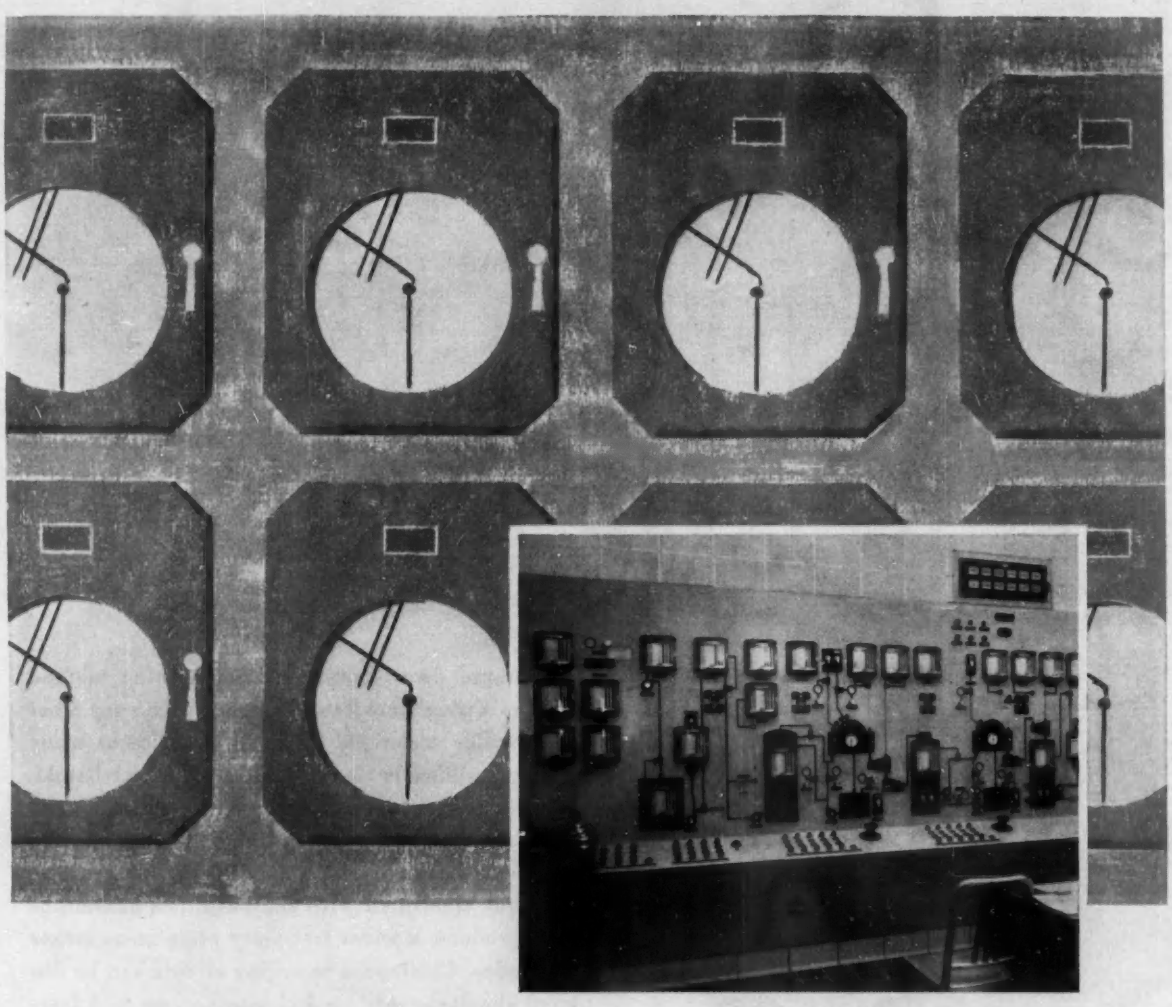
See the AO TRACE MASTER . . . plus other advanced direct writing recorder instrumentation at N.E.C. Booth 242 and N.E.R.E.M. Booth 804.

American Optical
COMPANY

INSTRUMENT DIVISION, BUFFALO 15, NEW YORK

CIRCLE 41 ON READER SERVICE CARD

off with the OLD...



"MAG-PIPE" Magnetic Flowmeter Transmitter permits . . . . . .

- CENTRALIZED CONTROL ROOMS
- USE OF MINIATURE INSTRUMENTATION
- TRANSMISSION UP TO 10,000 FEET WITH 1/2% ACCURACY

Taylor Instruments

on with the NEW!

New Taylor "MAG-PIPE"* Magnetic Flowmeter Transmitter permits use of miniature instruments to $ave Panel $pace . . . and, for the first time, gives High-Accuracy Transmission over great distances . . .

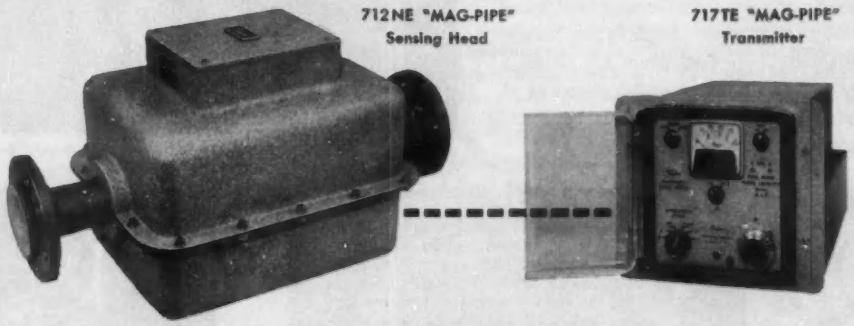
Not only does this outstanding new Taylor flow transmitter give you a very high degree of accuracy, it also permits conservation of panel space by use of miniature instruments, and transmission over greater distances. Designed to measure flow of fluids with an electrical conductivity as low as that of distilled water, it is ideally suited for very low flows, viscous liquids and liquids containing suspended solids. The flow is in no way restricted by the primary element.

The "MAG-PIPE" sensing head is mounted in the flow line. It comprises a flow pipe, an AC magnetic circuit and two electrodes. Sensing head housing is "hose-down proof" (explosion-proofing optional), and has lapped joint (Van Stone type) flanges for easier installation.

The transmitter employs solid state components, being fully transistorized for long-term reliability. It is standard in fixed-range form, in which case calibration is factory set at the desired range. Optionally available with a full-scale vernier adjustment and a 2-position range switch to measure any range between 1 and 30 ft./sec. A built-in output meter doubles as circuit checking device.

• • •

The "MAG-PIPE" Flowmeter Transmitter is in production. Consult with us on your difficult flow measurement problems. See your Taylor Field Engineer or write for **Bulletin 98418.** Taylor Instrument Companies, Rochester, N.Y., and Toronto, Ontario.



OUTSTANDING FEATURES

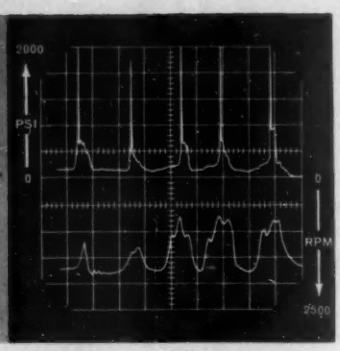
• High accuracy—one-half percent of full scale on most ranges • Full scale velocities as low as ½ ft./sec. at only slightly reduced accuracy • Conductivity range—as low as distilled water • Rangeability—½ to 30 ft./sec. full scale calibration, continuous vernier adjustment • Amplifier—solid state • Output signal—1-5 ma DC into any load from 0-3000 ohms. (Electro-Pneumatic Transducer or TRANSCOPE Electronic Control System).

*Trade-Mark

MEAN ACCURACY FIRST

CIRCLE 43 ON READER SERVICE CARD 43

Hydraulic system *pressure* ..... *vs* ..... Engine *speed*



Displayed on Tektronix Dual-Beam Oscilloscope

Here is one way in which an oscilloscope can be used to solve a mechanical problem . . .

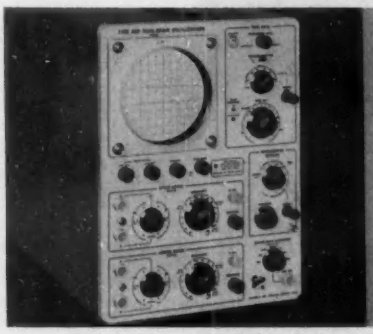
In evaluating a pilot model of a 2500-pound-capacity Lift Truck, HYSTER COMPANY Proving-Ground Engineers wanted to monitor pressure surges in the hydraulic system against a standard of engine speed.

To observe both actions simultaneously, they incorporated a Tektronix Type 502 Dual-Beam Oscilloscope in a specially-designed, precision-measurement field console.

Using strain-gage techniques in testing the oil lines of the hydraulic system, the Proving-Ground Engineers were able to display and measure precise changes occurring during lifting and lowering under various load conditions.

For your own mechanical applications—in displaying information from strain gages, accelerometers, thermocouples, pressure transducers, differential transformers, similar devices—or your medical applications or laboratory applications demanding dual-beam displays on linear time bases at high sensitivity . . . or dual-beam X-Y displays at medium sensitivity . . . or single-beam X-Y displays at high sensitivity . . . please consider a Tektronix Type 502 Dual-Beam Oscilloscope.

photographed at HYSTER COMPANY PROVING GROUND, Portland, Oregon



Type 502 performance characteristics include: calibrated vertical sensitivity in 16 steps from 200 μv/cm to 20 v/cm, both beams, calibrated sweep range in 21 rates from 1 μsec/cm to 5 sec/cm, constant input impedance and differential input at all sensitivities. Other Tektronix features include: flexible trigger facilities, 2X, 5X, 10X, or 20X sweep magnification, amplitude calibrator, electronically-regulated power supplies.

Type 502 Dual-Beam Oscilloscope $825
(f.o.b. factory)

TEKTRONIX®

FOR A DEMONSTRATION OF THE TYPE 502 OSCILLOSCOPE **IN YOUR OWN APPLICATION**, PLEASE CALL YOUR TEKTRONIX FIELD ENGINEER.

Tektronix, Inc. *P. O. BOX 500 · BEAVERTON, OREGON / Mitchell 4-0161 · TWX—BEAV 311 · Cable: TEKTRONIX*

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ENGINEERING REPRESENTATIVES: Kentron Hawaii Ltd., Honolulu, Hawaii. Tektronix is represented in twenty-five overseas countries by qualified engineering organizations.

European and African countries, the countries of Lebanon and Turkey, please contact TEKTRONIX INTERNATIONAL A.G., Terrassenweg 1A, Zug, Switzerland, for the name of your local engineering representative. Other Overseas areas, please write or cable directly to Tektronix, Inc., International Marketing Department, P. O. Box 500, Beaverton, Oregon, U.S.A. Cable: TEKTRONIX.

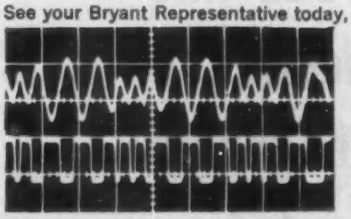
BREAKTHROUGH FROM BRYANT

NEW LOW-COST FAIL-SAFE FLYING HEADS

Now . . . at no increase in cost over previous fixed head designs . . . Bryant announces the first flying heads for magnetic drums offering complete protection from drum damage due to environmental conditions or human error. Their features include:

- Non-contact, start-stop, fail-safe design
- Improved resolution (300 bits/inch standard)
- Adjustability to match playbacks
- Unlimited recording modes
- Inductance variable to match user circuitry
- Complete head shielding for reduced crosstalk
- Increased track density (to 64 tracks/inch)

See your Bryant Representative today, or write direct.



High Density Playback Wave Forms
Upper trace:
Playback at head, 50 millivolts/cm
Lower trace:
Playback from amplifier: 5 volts/cm
Conditions:
350 PPI, phase modulation,
500 KC, 1416 in/sec surface speed.

BRYANT

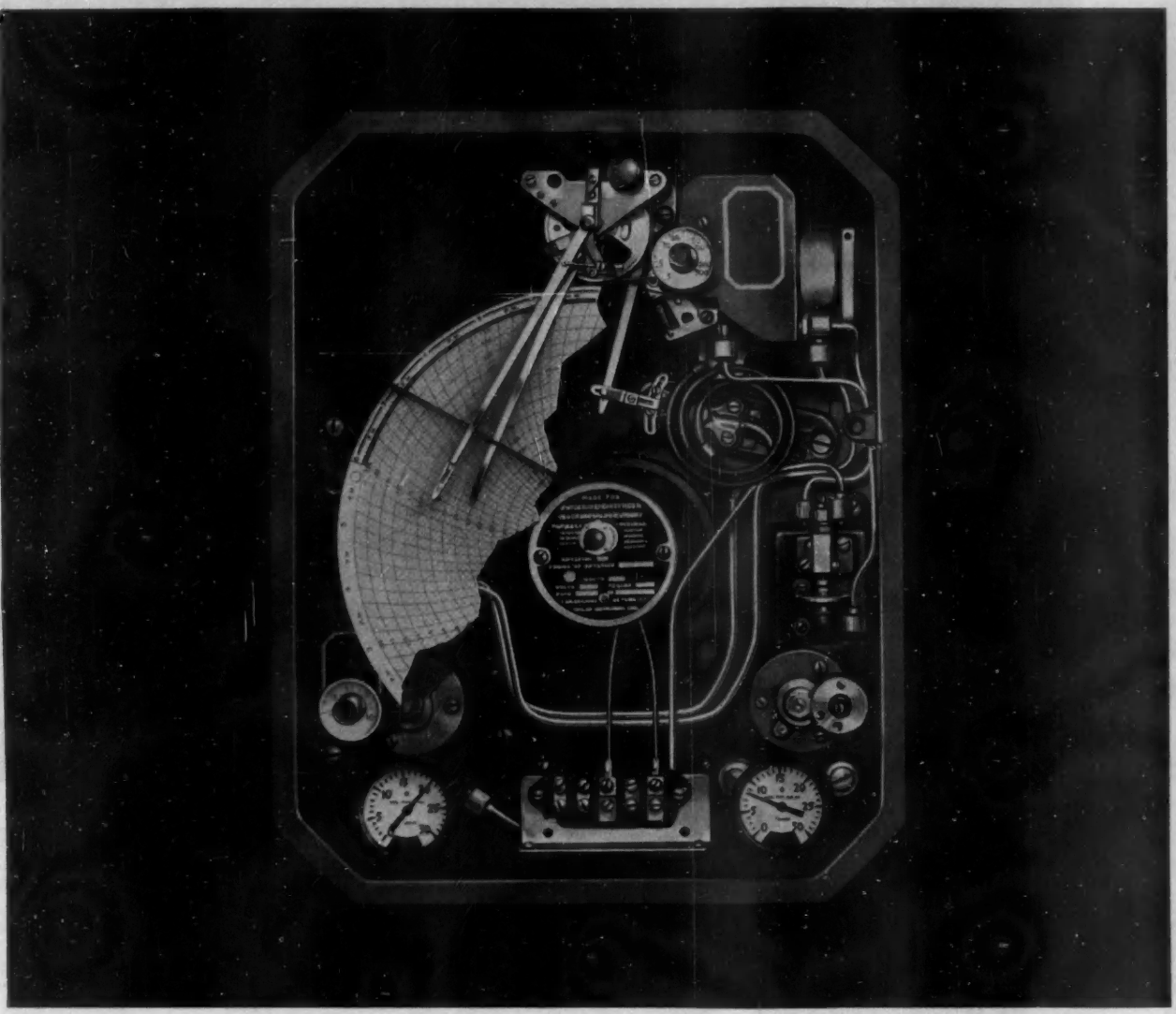
COMPUTER PRODUCTS

Disc File and Magnetic Drum Memories for Every Storage Application
852 Ladd Road • Walled Lake, Michigan • MArket 4-4571
A DIVISION OF EX-CELL-O CORPORATION

61-40 CP

CIRCLE 45 ON READER SERVICE CARD

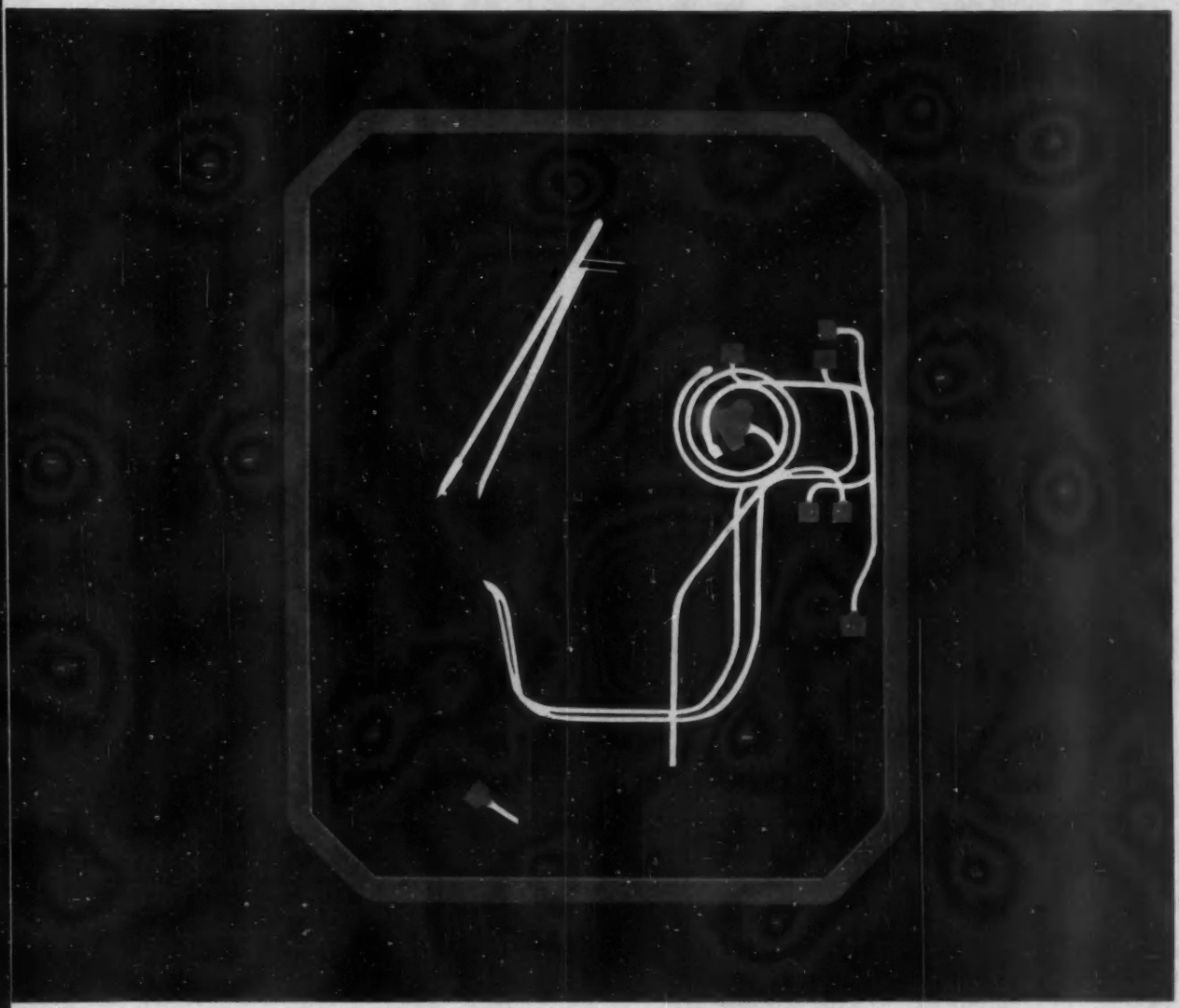
Tomorrow's tubing technology—today



Superior's broad line simplifies selection of small-diameter tubing for instrumentation

Indicating, recording and controlling instruments, more than any other type of precision products, demand fine-quality small-diameter tubing. It can be used for three major applications: (1) as conveyors for the liquid or gas which operates the fluid-filled systems; (2) as strong, light structural elements in linkages, pointers, pen tips and other parts; (3) as special-purpose elements, such as torque tubes, Bourdon tubes, bellows and thermocouple sheathing.

To satisfy the instrument designers' and makers' requirements for small-diameter tubing, we offer a broad line of specialty tubing — thermometer bulb, capillary, Bourdon, torque, bellows, thermocouple protection, fire detection, linkage and recording pen; also tubing for thermocouples and gas chromatography. We offer a wide variety of materials, too. Moreover, we have the metallurgical competence and manufacturing skills to save experimentation in the design stage . . . time and money in production. Bulletin 380, "Specialty Tubing for Industrial Instrumentation," gives details. Write for your copy today. Superior Tube Company, 2026 Germantown Ave., Norristown, Pa.



CAPILLARY TUBING
We have devoted years to the development of manufacturing processes and quality control procedures for the production of close tolerance capillary tubing. ODs range up to 3/16 in., IDs from .004 through .040 in., lengths up to 3000 ft. Analyses include Types 304, 316, 321, 347 and 446 stainless; also Monel,[1] Inconel,[1] nickel and carbon steels.

BOURDON TUBING
A wide range of materials, including beryllium copper, Ni Span C,[1] K Monel,[1] 4130 alloy steel, stainless steels and Inconel X.[1] All are free of inclusions and seams, carburization and decarburization, rough and corroded surfaces, and variations in wall thickness. All offer good creep resistance, low hysteresis, nonrelaxation and excellent fatigue life.

LINKAGE TUBING
Hypoflex,® our stainless steel Type 304 needle tubing, is widely preferred due to high strength and corrosion resistance. Other materials frequently specified to meet particular corrosion requirements are Monel, A Nickel,[1] Inconel and titanium. ODs under .250 in., and walls thin as practicable, i.e., from .015 to .035 in., are usually specified. But any OD, ID or wall within our range can be had.

RECORDING PEN TUBING
Of the Stainless 300 Series, our Hypoflex tubing is most frequently chosen. Other desirable materials are nickel, Monel, Haynes 25[2] and Inconel. Generally ODs from .028 to .050 in., walls from .00625 to .0085 in. are found to promote the best flow rate for ink-carrying systems. In some cases a smaller tube is required for the pen point.

[1]Registered TM International Nickel Company [2]Registered TM Haynes-Stellite Co.

Superior Tube ST

The big name in small tubing
NORRISTOWN, PA.
West Coast: Pacific Tube Company, Los Angeles, California

CIRCLE 47 ON READER SERVICE CARD

Snap Experimental Reactor

DEVELOPING THE WORLD'S SMALLEST NUCLEAR REACTOR POWER PLANT

In the next decade, man will enter the vast new world of outer space. An important factor in his ability to fully utilize this new environment will be auxiliary electrical power. Atomics International is developing SNAP (Systems for Nuclear Auxiliary Power) reactors for the AEC which will generate many kilowatts of electricity, operate unattended for long periods in space and weigh only several hundred pounds.

Compact reactor projects at AI provide challenging opportunities for engineers and scientists interested in contributing to the practical utilization of space. Positions are available in the following areas:

Heat Transfer. Engineering analysis in the fields of heat transfer and fluid mechanics. Responsibilities will include systems engineering studies on the thermal, hydraulic and thermodynamic performance of advanced reactor systems.

Systems and Control Analysis. Analysis and simulation of complete nuclear power plants to develop reliable, unattended, automatic control and instrumentation systems, including reactor kinetics, dynamics, stability and thermal characteristics and reliability analysis.

Reactor Analysis. Complete nuclear thermal and structural analysis including criticality, flux and power distributions and fuel cycle analysis.

Reactor Operations Evaluation. To establish detailed operating procedures, direct operations, and evaluate the performance characteristics of compact, lightweight nuclear systems for space applications.

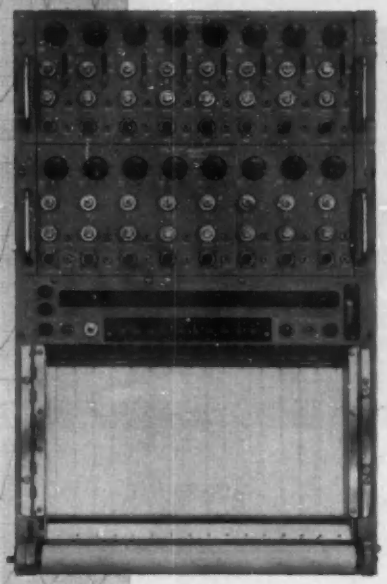
Metallurgical Development. Several years experience in the application and usage of high temperature radiation resistant materials, including the joining of these materials. For application to the development of advanced lightweight control systems, pumps, thermoelectric generators, etc.

Preliminary Design. Several years experience in reactor systems analysis and design with interest and ability in preliminary analysis and design of advanced nuclear systems for space and terrestrial uses.

Please contact: Mr. C. K. Newton,
Personnel Office, Atomics International,
8900 DeSoto Avenue, Canoga Park, Calif.

All qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin.

ATOMICS INTERNATIONAL
DIVISION OF NORTH AMERICAN AVIATION

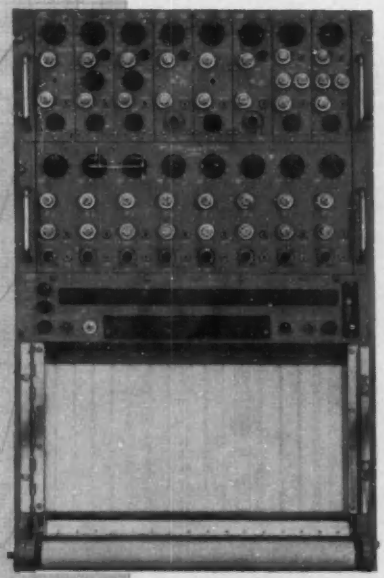


. . . with Sanborn® High, Medium or Low Gain 8-Channel Amplifiers and Flush-Front Recorder in only 32″ of panel space

In the 32″ panel space version, Sanborn 16-channel direct writing systems use a flush-front 358-16 Recorder and *any two* "950" series 8-channel amplifiers — available in transistorized high and medium gain types with floating and guarded inputs, low gain with high resistance balanced to ground inputs. Max. sensitivities are 20 uv/mm, 1 mv/mm and 20 mv/mm for high, medium and low gain systems. Frequency response ranges for the three are 100, 125 and 125 cps. Recorder has 9 chart speeds, 8″ of visible record, inkless recording in true rectangular coordinates on Sanborn Permapaper® charts.

RECORD 16 VARIABLES

on a single 16″ chart



. . . with 8 channels identical, 8 more with miniature plug-in preamplifiers for greater flexibility

Eight interchangeable, plug-in "850" preamplifiers, each with 7″ x 2″ panel, plug into chassis with common power supply. Available types are Phase-Sensitive Demodulator, DC Coupling, Carrier and Low Level; MOPA available for Carrier and Low Level excitation. Frequency response is DC to 125 cps, 3 db down at 10 mm peak-to-peak depending on type of preamplifier. Linearity is better than 0.5%. Inputs are single-ended, floating and guarded, or push-pull, depending on type of "850" preamplifier used. Remaining eight channels can comprise any 8-channel "950" amplifier.

With each of these systems, you have a choice of vertical or horizontal chart plane recorders. Flush-front vertical recorder ("350" style) has electrical speed shift, requires only 17½″ vertical panel space. Horizontal recorder facilitates viewing and making notations on record, occupies 21½″ of panel space, has mechanical speed shift. Both recorders have velocity feedback-damped galvanometers . . . automatic stylus heat control . . . separate timer/marker stylus . . . inkless direct writing on quick loading, rectangular coordinate charts with 20 mm wide channels.

For complete specifications and application engineering assistance, contact your nearest Sanborn Sales-Engineering Representative. Offices throughout the U. S., Canada and foreign countries.

INDUSTRIAL DIVISION
SANBORN COMPANY
175 Wyman St., Waltham 54, Mass.

CIRCLE 49 ON READER SERVICE CARD

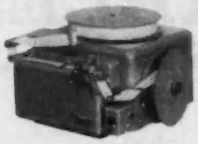
find the solution to your printing problems

at Clary

...America's foremost producer of printers

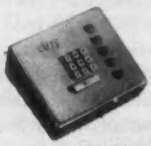
Other Clary printers include:

TIME-DATA PRINTER. Accepts remote source information, records it with exact time to nearest second.



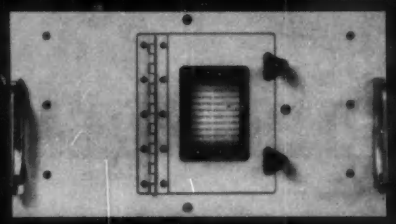
TAPE PERFORATOR. Records data on punched tape. Has self-contained power supply, parallel to serial convertor.

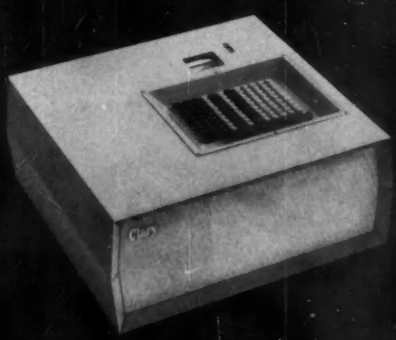
PRINTING TIMER. Measures and prints elapsed time and sequential number of operations in series.



INPUT DATA UNIT. Works with any computer, check-out, data-logging, testing, or other system.

COMMERCIAL PRINTER. Utilizes the Militarized printer's principle of reliable high-speed motion.





MILITARIZED PRINTER:
Uses an exclusive printing method that ends critical timing problems, messy ribbon changes, bleeding of ink into paper. Prints up to 21 characters per line, 600 lines per minute. Withstands 50G shock, prints in sub-zero temperatures, and under other extreme conditions. Used on new nuclear subs, and on the Polaris, Minuteman, Atlas missile programs.

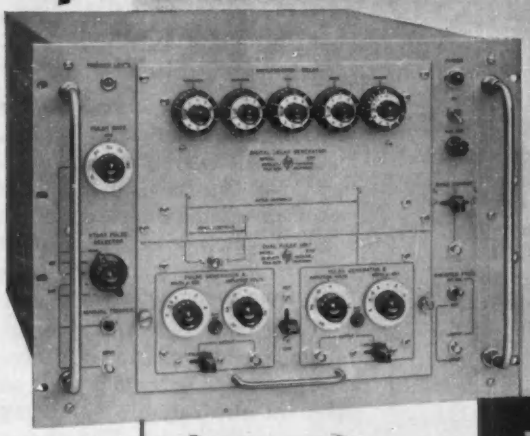
SCANNING PRINTER:
Accepts decimal *and* binary coded data on the same line, at *no* extra cost. Operates directly from the voltage output, draws negligible power from data source. Color-prints outputs from digital voltmeters, shaft position transducers, electronic counters, digital clocks, etc. at 3 lines per second, with 12 digits per line capacity. Fewer moving parts make it more reliable.

SOLENOID PRINTERS:
One of the world's largest selection of standard, serial entry, and parallel entry printers. Choose the exact one you need for your business, industrial, or instrumentation application. Simple circuitry, engineering experience make them more reliable; production-line economies make them lower in cost. Seven-day delivery, or custom-designed to your specification.

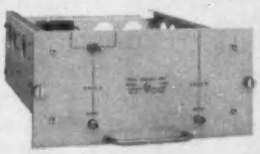
Let Clary help you solve your printing problems. Just write or call direct.

Clary ELECTRONICS
San Gabriel, California
Canada: Computing Devices of Canada, Ltd., Ottawa

MEASURE TIME; 0.1 μsec ACCURACY!



hp 218AR Digital Delay Generator produces crystal controlled pulses accurately spaced in time. Pulses or time intervals are initiated by an internal rate generator or an external trigger. The instrument is thus both a digital delay generator and an extremely high accuracy laboratory pulse generator.



hp 219A

hp 219B

hp 219C

Time measurement and pulse simulation in radar, loran, Tacan, DME, oscilloscopes, computers, fast gates, pulse code systems—almost any kind of time measurement single- or double-pulse simulation is now yours quickly and accurately with hp 218AR Digital Delay Generator.

Built along strict military standards, hp 218AR uses a pulsed crystal oscillator synchronizable in *constant phase* with an initial trigger pulse (zero time) to position the two terminating pulses. Time is counted with a 1 megacycle preset counter, and two independent output pulses are available in any relationship.

PULSE GENERATOR PLUG-INS

For utmost versatility, output pulses are generated in various arrangements by three plug-in pulse generators. These include hp 219A, supplying two positive pulses, hp 219B providing two pulses, each positive or negative and variable in amplitude, hp 219C, providing a high power pulse, positive or negative, digitally controlled as to delay and duration, variable in amplitude.

Condensed Specifications

(Basic 218AR Generator; plug-ins essential)

Time Interval Range:	1 to 10,000 μsec	**Recovery Time:**	50 μsec or 10% of interval, whichever is greater
Accuracy:	± 0.1 μsec ± 0.001%	**Sync Output:**	50 v pos. pulse, 0.1 μsec rise time
Digital Adjustment:	1 μsec steps, full range	**1 MC Output:**	1 v pulses, 500 ohm impedance
Interpolation:	Variable 0 to 1 μsec	**Price:**	-hp- 218A, $2,000.00 -hp- 219A Dual Trigger Unit, $100.00 -hp- 219B Dual Pulse Unit, $450.00 -hp- 219C Digital Pulse Duration Unit, $350.00
Input Trigger:	Internal 10 cps to 10 KC; External 0 to 10 kc pulses, also sine wave		
Jitter:	0.02 μsec or less		

Data subject to change without notice. Prices f.o.b. factory

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Cable "HEWPACK" • DAvenport 6-7000

Field representatives in all principal areas

hp World leader in precision electronic counting

CREATIVE CONTROVERSY IN INERTIAL GUIDANCE

Behind the inertial package you see here is the instructive history of a creative controversy.

It's the history of how the ingenious rebuttals of some Litton Systems people won an engineering debate by overcoming certain obstacles that had been roadblocking progress in airborne inertial navigation.

The equipment shown is the stable-platform unit of a Litton LN-3 navaid system, first to furnish operational aircraft with inertial navigation information to an accuracy within 1.5 nautical miles for each hour of varied flight maneuvers.

The debate: It had been known that an inertial platform could be built around two two-degree-of-freedom gyros in place of the three one-degree-of-freedom gyros that were the standard concept. And that such a change would offer a number of important advantages including high gyro angular momentum in a compact platform, better servo response characteristics, and freedom from air-bubble problems achieved through the use of low-viscosity damping fluid.

Many inertial engineers felt strongly that the difficulties encountered in trying to manufacture two-degree-of-freedom gyros would more than offset the promised benefits. The difficulty regarded with the most superstitious awe was the problem of adjusting the center of gravity, center of buoyancy and total weight of the float containing the gyro to achieve neutral buoyancy at a specified temperature and zero torque about all three axes, within extremely narrow tolerances.

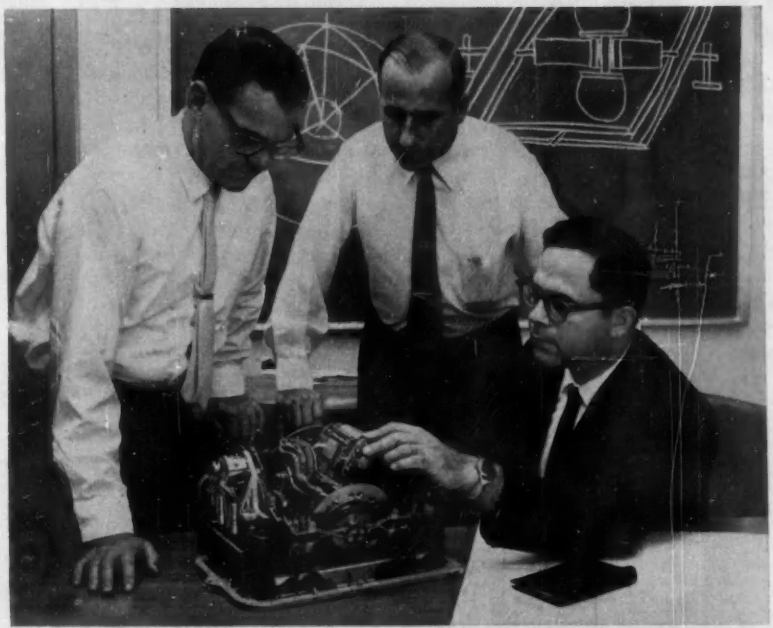
The additional restriction, that the weights placed on the float for balancing shall fall between a minimum and a maximum allowable size, increases the complexity of the actual balance procedure, placing it in the "linear programming" category from a computer standpoint.

The problem was solved by being programmed for solution on a digital computer in order to provide an efficient and reliable balancing process in production. The success of this approach is demonstrated by the world-wide operation of the Litton LN-3 aircraft navigation system, a proven lightweight system of high accuracy that uses two-degree-of-freedom gyros.

The same approach is being used to expedite the development of even more advanced systems, which will assure Litton's dominant position in the field. They include the Litton Doppler-Inertial System for the P3V anti-submarine patrol aircraft and the P-300 inertial platform of the Air Force Flight Data System for orbital and sub-orbital vehicles.

It's good to work in the atmosphere engendered when management fully appreciates the value of creative controversy that produces such results. Like-minded design and production engineers with applicable experience couldn't do better than to contact N. M. Pagan, Litton Systems, Inc., Guidance & Control Systems Division, 5500 Canoga Avenue, Woodland Hills, California.

An equal opportunity employer



L-R: BRUCE SAWYER, HEAD OF ELECTROMECHANICAL ENGINEERING DEPARTMENT; GEORGE NORTHWAY, HEAD, GIMBAL SYSTEMS ENGINEERING; HAROLD ERDLEY, DIRECTOR OF ELECTROMECHANICAL PRODUCTS, GUIDANCE & CONTROL SYSTEMS DIVISION.

LITTON SYSTEMS, INC.

A DIVISION OF LITTON INDUSTRIES

GUIDANCE & CONTROL SYSTEMS · COMPUTER SYSTEMS · DATA HANDLING & DISPLAY SYSTEMS · SPACE SCIENCE · BIOELECTRONICS · ADVANCED COMMUNICATIONS TECHNOLOGY

. . . "Frictionless" design gives Flexotrol* longest life, stability and accuracy of any displacement level controller

By avoiding knife edges, bearings and associated pressure-tight mechanical fittings, K & M has achieved almost frictionless operation in the *Flexotrol* Displacement-Type Liquid Level Controller. As a result, errors due to friction, distortion and hysteresis are practically nil.

Actuation is accomplished through a torque element which directly transfers displacer movement to the controller. There are no intermediate levers. Because the rotation of the tube is limited (4°) and because the whole assembly is constructed of high-durability materials, the torque system has remarkable fatigue resistance. Tests in excess of five million operating cycles have produced no detrimental fatigue effect.

The controller unit utilizes conventional 3-15 psi signal air pressure, has a 0-150% adjustable proportional band, may be direct-, reverse- or snap-acting without parts change. The *Flexotrol* Level Controller can also be converted to a transmitter-controller combination. Automatic reset and rate response are optionally available.

Full details are given in Bulletin 456-1. A copy is yours for the asking.

*Flexotrol is a trade-name of Kieley & Mueller, Inc.

K&M

diaphragm control valves

Our 80th Year

KIELEY & MUELLER, INCORPORATED

Oldest Pressure and Level Control Valve Manufacturer

64 Genung Street, Middletown, New York

U.A. 1929

Painting in background: "The Piping Shepherd," by Sir Joshua Reynolds, P. R. A. (1723–1792)

New cost savings for users of dielectric materials

. . . a progress report on the MYCALEX METHOD
from Jerome Taishoff, President, Mycalex Corporation of America

"I don't have to tell you about the profit squeeze. It's a hard fact-of-life throughout our industry today. That's why we feel the *MYCALEX METHOD*—the unique molding and finishing technique we recently developed—offers so much promise.

Sample quotations point to cost savings up to 84%

"The many months spent in the developing of this new process enable us to turn out better-performing products for less: savings we, in line with our policy, will pass along directly to our customers. And those savings promise to be substantial! Note the typical parts shown in the photograph below, as well as the two mechanical diagrams. As you can see, this new production technique reveals cost reductions of 78% and 84%, respectively, when compared to previous cost quotations." Just as important, the savings are in *addition to* the high reliability SUPRAMICA® ceramoplastics and MYCALEX® glass-bonded micas are noted for.

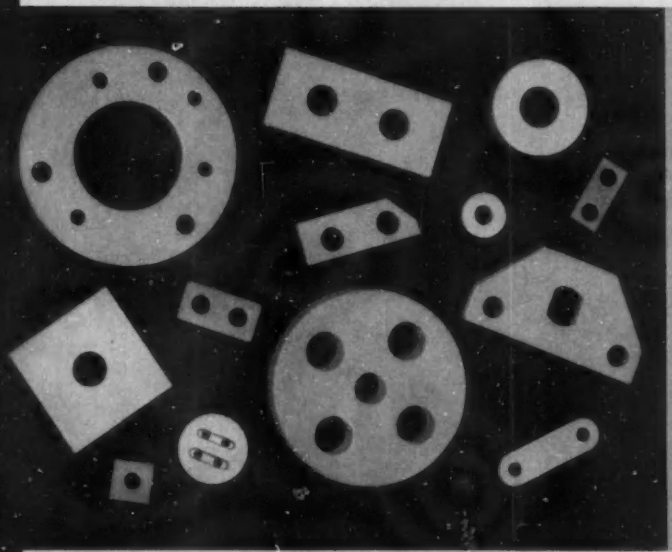
Savings plus quality with the MYCALEX METHOD

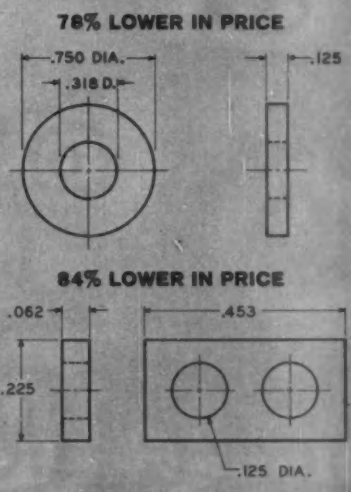
Though these intricate parts now cost much less to make—they offer the temperature endurance, total dimensional stability, high dielectric strength and low loss that SUPRAMICA and MYCALEX formulations have been delivering for years.

Choose from any of these famous materials

SUPRAMICA 620 "BB", 560 and 555 ceramoplastics and MYCALEX 410 glass-bonded mica. *Maximum Temperature Endurance* (unstressed): 1200, 930, 650 and 650°F; *Loss Factor* (10^6 cycles/sec.): 0.020, 0.010, 0.013, 0.010; *Compressive Strength* (psi): 30,000, 25,000, 40,000 and 40,000, respectively.

So for electronic insulation materials with the high-performance properties you must have—at a profit-protecting price — look into the new *MYCALEX METHOD*. Send your blueprints and drawings for specific quotations and information.





We are exhibiting at the N.E.C. Show
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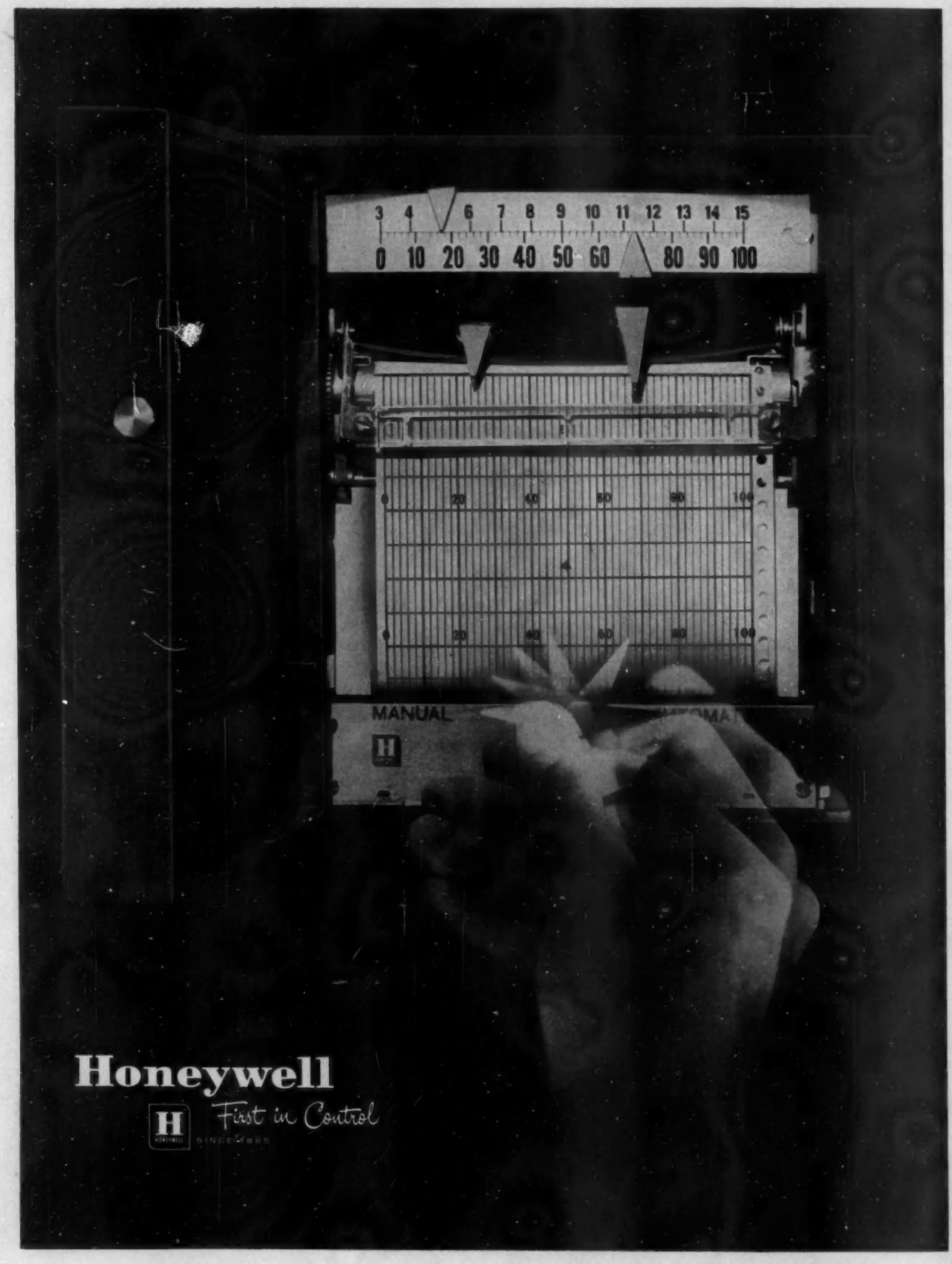
World's largest manufacturer of ceramoplastics, glass-bonded mica and synthetic mica products

SYNTHANIC® SYNTHETIC MICA · SINCE 1910 MYCALEX® GLASS-BONDED MICA · SUPRAMICA® CERAMOPLASTIC

MYCALEX
CORPORATION OF AMERICA


3 4 6 7 8 9 10 11 12 13 14 15
0 10 20 30 40 50 60 80 90 100
MANUAL
Honeywell
First in Control

Automatic Switching Eliminates Matching of Pressures *with*

New Honeywell PneumatiK Tel-O-Set Instrumentation

Honeywell brings new features, new performance to small case instruments with the introduction of *PneumatiK Tel-O-Set Instrumentation*. Here are just a few of the many new features:

Automatic Switching Just a flip of the control lever switches the instrument from automatic to manual or vice versa. There are no bumps, no delays, no matching of pressures required. This simplified switching makes cascade control systems practical for the operator.

Easily accessible adjustments Zero and damping adjustments to pen can be made while the pen is recording. Effects of adjustments can be seen *while* they are being made. Since it is not necessary to withdraw the recording chassis to make adjustments, there is no possibility of causing a pen zero shift.

Interchangeable chassis and controllers Recording and indicating chassis are interchangeable. Just pull out one chassis and plug in the other. Quick-connect air terminals eliminate the need for tubing connections. Two- and three-mode controllers with backset adjustments are also completely interchangeable.

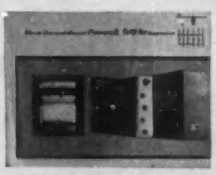
Easy-to-read, easy-to-change 4-inch charts Pen position on the 4-inch chart permits instantaneous reading of variables at all times. Pen arm design also permits rectilinear recording. Front-loading, tilt-out chart drive makes it easy to change chart rolls in a matter of minutes.

All cases fit 6 x 6 cutouts All models fit standard panel cutout of 6″ x 6″. Overall dimensions: 6¾″ wide; 7½″ high; 15¼″ deep.

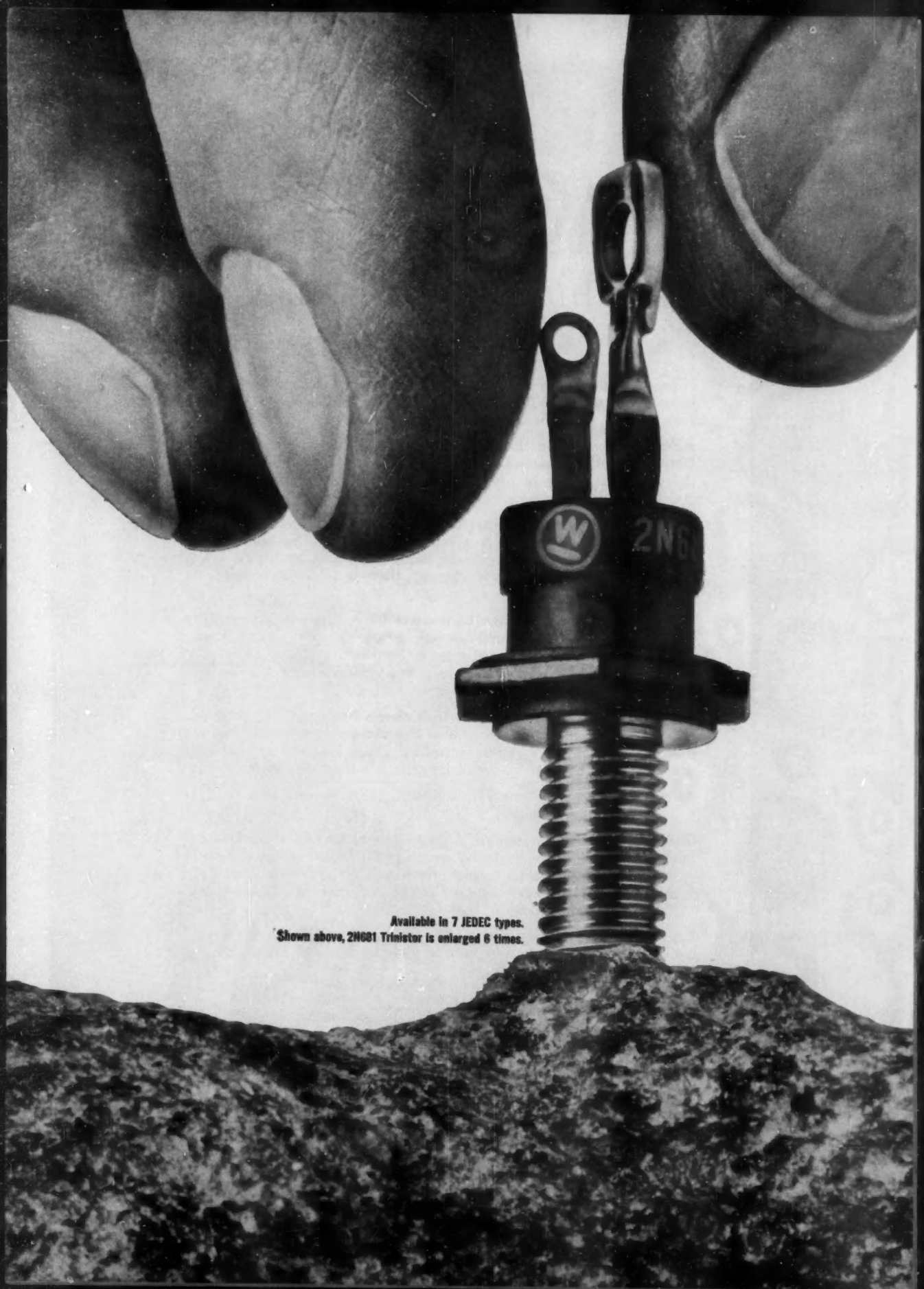
Calibrated control adjustment Adjustments to controller can be easily made from back of the panel by removing controller cover. Calibrated dials for each adjustment ensure precise setting of proportional band, reset and rate values. Optional front-set control adjustments make it easy to set control from front of panel.

Easy to remove components To remove any particular component from the case, it is only necessary to loosen a screw or lift a latch.

HANDY DEMONSTRATOR-IN-PRINT Get the full story on new Honeywell *PneumatiK Tel-O-Set* Instrumentation by writing for this handy demonstration-in-print. This booklet covers in words and pictures all the important installation, operation and maintenance features of the new line. It will help you evaluate the many advantages *PneumatiK Tel-O-Set* holds for your process. Send for it today. MINNEAPOLIS-HONEYWELL, 4401 Wayne Avenue, Philadelphia 44, Pa. In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.



HONEYWELL INTERNATIONAL Sales and Service offices in principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.



Available in 7 JEDEC types.
Shown above, 2N681 Trinistor is enlarged 6 times.

Westinghouse announces new 16-amp "Rock-Top" Trinistor® controlled rectifier

Proven "Rock-Top" quality is now available in JEDEC 2N681 Trinistor Controlled Rectifier series! These latest additions to the Westinghouse power semiconductor family incorporate the field-proven design features of the broadest line of medium and high-power switching devices. Such features as hard-soldered junctions and hermetically welded cases provide an extra assurance of reliability at no extra cost. Additionally, each device is 100% tested to maximum ratings. These new devices from Westinghouse, world leader in silicon technology, are backed by production experience with high-power semiconductors for military and industrial applications.

Westinghouse 2N681 series Trinistors are ideal for such applications as: motor speed control ▪ temperature control ▪ inverters ▪ static switching. For more information, or technical assistance, call or write: Westinghouse Electric Corporation, Semiconductor Dept., Youngwood, Penna. *You can be sure...if it's Westinghouse.* SC-1049

For prompt delivery, order from these Westinghouse distributors:

EASTERN

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CAMERADIO	Pittsburgh, Pa./EX 1-4000
CRAMER ELECTRONICS, INC.	Boston, Mass./CO 7-4700
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MIDWESTERN

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LENERT CO.	Houston, Texas/CA 4-2663
MIDLAND SPECIALTY CO.	El Paso, Texas/KE 3-955[illegible] Phoenix, Ariz./AL 9-82[illegible] Albuquerque, N. M./CH 7-01[illegible]
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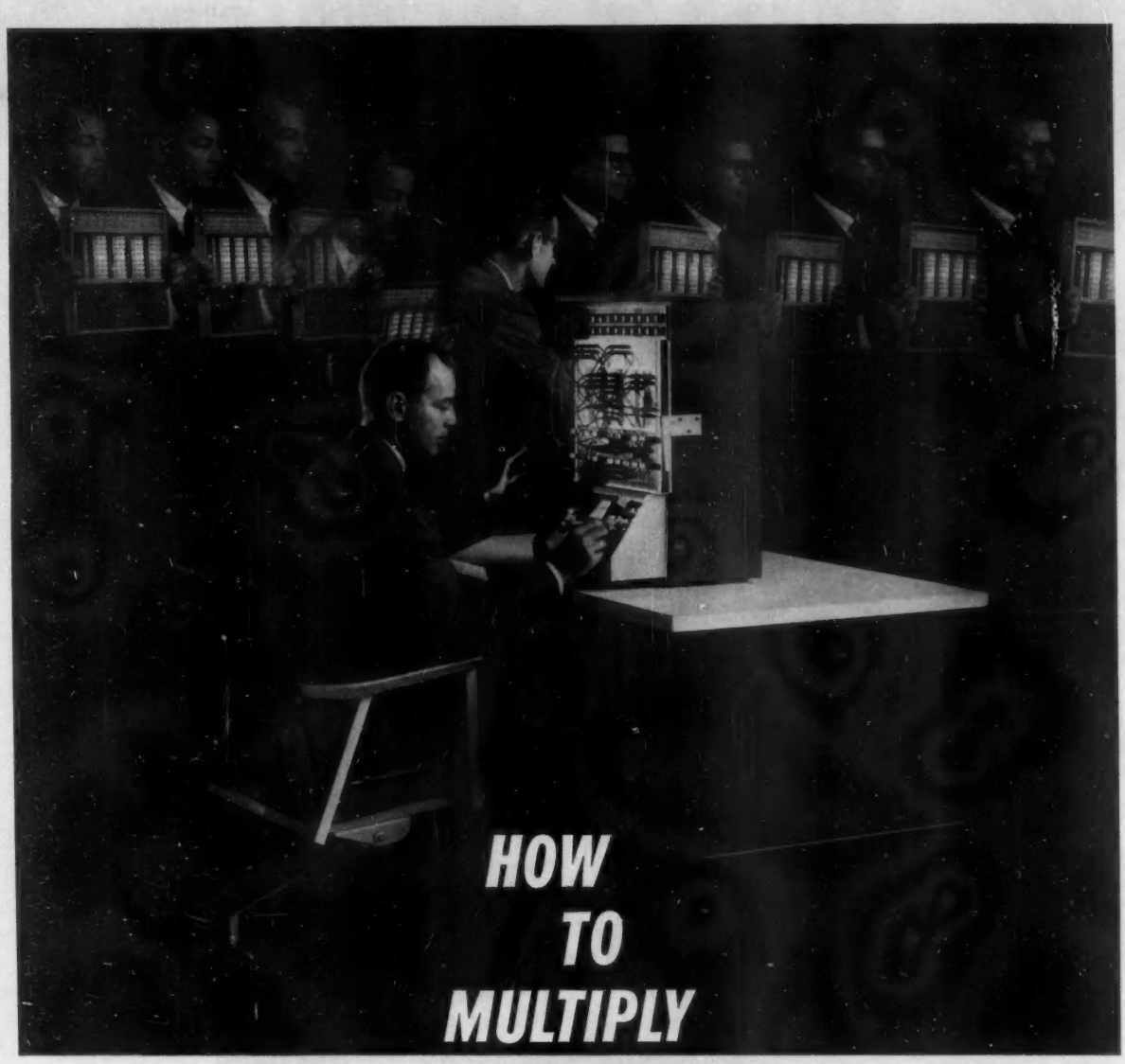
CIRCLE 59 ON READER SERVICE CARD

Westinghouse



HOW TO MULTIPLY ENGINEERS

One engineer and an EAI PACE TR-10 transistorized desktop analog computer can be the equal of several men limited to conventional design tools. The TR-10 multiplies the design capabilities of the most able engineer. One TR-10, equipped with a removable patch panel, will serve the needs of a roomful of engineers. This new patch panel permits pre-patching of programs away from the computer. It plugs into the computer instantly — valuable computation time is conserved. ■ *Versatility of the TR-10 is unequalled. Unique simplicity makes it excellent for students or engineers unfamiliar with analog techniques. Accurate to a tenth of one percent, the TR-10 performs admirably for the experienced user in 95% of routine engineering problems. And with High-Speed Repetitive Operation added, or with several units slaved to operate as one, the TR-10 meets the demands of many advanced applications.* ■ *For technical data on this almost infinitely versatile computer, write for Bulletin No. AC 934.*

EAI ELECTRONIC ASSOCIATES, INC. *Long Branch, New Jersey*

Leader in Analogics Analog/Digital Computers Data Reduction Process Control Instruments Computation Service

Selling Electronics to Industrial Control Users

To many electronic manufacturers, the industrial market outside the electronic industry is turning out unexpectedly difficult to crack. It is like a mirage: tempting, fabulously rich-looking, but apparently unreachable. When the seller closes in, the market seems to disappear.

What's wrong, a market research project* hypothesized last month, is that many electronic manufacturers are not well enough acquainted with the customs and practices of this broad industrial market. And the makers are not patronizing the best channels of distribution.

Three kinds of customers

The study took a look at three promising kinds of customers: raw materials processors, original equipment manufacturers that might incorporate electronic goods into their end products as well as use them in manufacturing, and general manufacturers and fabricators that might employ electronic devices and controls in the manufacturing process. It found a promising market:

Customer	No. of Units	1958 Capital Expenditures	1958 Control Purchases[1]
Raw materials processors	9,267	$3,203,521,000	$208,000,000
Original equipment mfg.	18,688	623,273,000	149,500,000
General manufacturers	46,244	1,076,608,000	258,000,000
	74,199	$4,903,402,000	$615,500,000

[1] Estimated; includes instrumentation and measurement equipment.

Not all the products in the control purchases are electronic. Pneumatic, hydraulic, mechanical, and electrical controls are still popular with these customers.

Wrong buying influences?

Such popularity, in fact, highlights one of the selling reasons electronic manufacturers may have difficulty cracking this market: many makers ignore it and try to reach imaginary buying influences. The study surveyed sales managers of electronic manufacturers as well as purchasing agents of potential customers asking each the same question: "*Who, by title, influences the purchase of electronic systems, subsystems, instruments, and components*"? The replies from the electronic companies sales managers did not agree at all with those from the customers. Here's how the two groups stated their first six preferences (out of 14 titles):

*"*Distribution Channels For Selling Electronic Equipment to Manufacturers Outside The Electronics Industry*", Lewis H. Young, Masters Thesis, Graduate School of Business Administration, N. Y. U.*

THE SIZE DIMINISHES; THE POWER REMAINS AS HIGH

Tiny New 3/8" (0.375") Squaretrim® Potentiometer Dissipates One Full Watt In Still Air!

The performance of this new Daystrom subminiature Squaretrim is as great as its half-inch cousins. Further, the one-watt rating is based on *still-air tests*...typical of our conservative specifications. Contained in a stackable package only ⅜" square and just ⅛" thick, the new Series 200 Squaretrims permit great circuit density (27 per cubic inch) and the 144 different models offered give wide design latitude. The Series 200 Squaretrims range from 10 ohms to 35K, operate from −55 to +150°C, and need no mounting brackets for stacking. A true precision instrument with all the exclusive features of the Daystrom line, this new potentiometer is designed to meet MIL R-27208 and MIL R-22097. Write for detailed information.

DAYSTROM, INCORPORATED
POTENTIOMETER DIVISION
ARCHBALD, PENNSYLVANIA • LOS ANGELES, CALIFORNIA

Named by Sales Managers	Named by Purchasing Agents
1. Buyer	1. Buyer
2. Project engineer	2. Chief engineer
3. Chief electronic engineer	3. Chief purchasing agent
4. Electronic engineer	4. Electrical engineer
5. Chief engineer	5. Plant superintendent
6. Chief purchasing agent	6. Chief electrical engineer

The significant conclusion to be reached is that electronic manufacturers try to sell to these industrial customers through the buying influences that are important *in the electronics industry*. Yet many of these potential customers have no electronic engineer or chief electronic engineer and the project system of organization has not yet been adopted. On the other hand, the study shows that the chief engineer, the electrical engineer, and the plant superintendent are regarded as more important buying influences.

Wrong channels?

Distribution is the second reason why electronic makers have trouble selling to this nonelectronic customer. The channels which electronic manufacturers have used widely are: the manufacturer's direct sales force, the independent manufacturers' representative, and the electronic parts distributor.

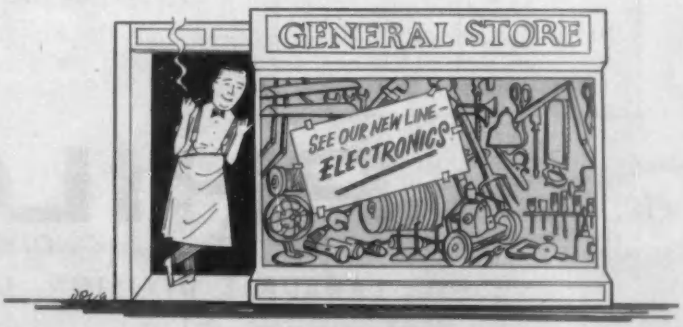
But these channels have not adapted to selling the nonelectronic customer. Because of the large number of these customers, over 50,000 companies with 74,000 plants distributed geographically from coast-to-coast, few manufacturers can afford a direct sales force to call on all these companies, unless they sell an expensive item whose market they know—such as a computer control system. Manufacturers' representatives say they prefer not to call on such customers because the representatives want electronic O.E.M. business with its large volume per customer. The electronic parts distributor too has concentrated on the electronics company.

Customer preference

In addition, the industrial customers showed a preference for buying from industrial distributors that already service them with such items as electrical apparatus—motors, circuit breakers, lighting, transformers, etc. Most frequently mentioned are the electrical wholesaler and the industrial mill and supply distributor. In fact, the customers indicated they were not accustomed to buying from manufacturers' representatives or electronic parts distributors.

New sales manager

The study also found that switching channels in midstream is no easy job for electronic makers. To sell through industrial distributors like the electrical wholesaler and the mill and supply house, the electronic manufacturer will have to train distributor salesmen thoroughly. A sales manager who sells the electronics industry well may not be good for distributor sales. The ability to teach, the talent for inspiring, and how to apply the company's products are more important than electronic design capability.



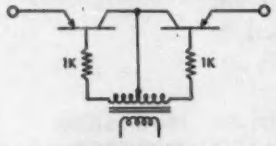
NEW PHILCO SILICON CHOPPERS

With SPAT.® Matched-Pair Uniformity Bring High Fidelity To Low Level Switching!

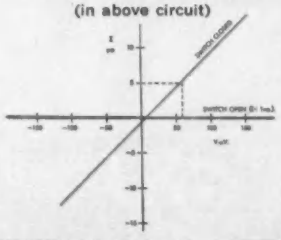
T2363 CHARACTERISTICS

Emitter Voltage, BV_{eco}	−30 volts
Collector Cutoff Current $I_{cbo}(V_{cb} = -10V)$	0.001 μa max.
Emitter Collector Current $I_{ecc}(V_{ec} = -10V)$	0.001 μa max.
Offset Voltage $V_{cc}(I_b = -200\ \mu a,\ I_c = 0)$	1.5 mv max.
Offset Voltage V_{cc}(T2357 Matched Pair, $I_b = -1ma$ at all temperatures from 25° to 85° C)	50 μv max.

TYPICAL CHOPPER CIRCUIT



T2363: I-V CHARACTERISTIC
(in above circuit)



For low level switching applications, Philco now makes available *Silicon Precision Alloy Transistor Choppers—produced on industry's only fully-automatic chopper production line—to assure the uniformity so important to matched pairs.

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- *High gain-bandwidth product;*
- *Meet all requirements of MIL-S-19500B.*

To assure ultra-high fidelity in multiplex systems for telemetry, multi-channel communications, analog computers, and other low level data handling applications, be sure to specify Philco SPAT® Choppers. For complete data, write Dept. CE1061.

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SOLID-STATE CENTER U.S.A.

CIRCLE 64 ON READER SERVICE CARD

Control
ENGINEERING

OCTOBER 1961

Which One of Many

A few years ago there was available one electronic process control system, two or three different numerical control systems, one production monitoring system, one make of process control computer, and one brand of many other new types of automatic systems. The decision to buy a specific system was based on the gains to be achieved by using this new approach; a decision not complicated by having to decide between competitive items since there was usually not more than one or two systems that would do the job.

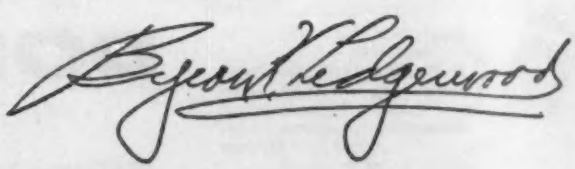
Although often the purchase of these "first available" systems was justified by a well-grounded technical and economic study, many were bought for purposes of experiment and curiosity, sometimes by user company personnel who had little or no knowledge of the characteristics or merit of the equipment. Purchasing influence was taken out of the hands of the man who really understood the system, the control engineer.

But today things are different. There are many highly competitive control devices available in each of the newer types of equipment. And you can't honestly feel you have the best system for a particular job without evaluating each available unit. This takes training and experience.

Nowhere is this more evident than in the field of general purpose digital computers, where new machines and new auxiliary equipments are springing up every day. The decision to install new computer capacity involves a long and detailed study of each system that could fill the bill, and as information systems tie together larger and larger segments of business and production operations, the control engineer will be increasingly in a position of deciding which computing system to select.

Recognizing this need for precise knowledge, this issue of CONTROL ENGINEERING starts an extensive series of articles comparing the characteristics of general purpose digital computers to a depth never attempted before. The gross characteristics such as memory capacity, add time, and cards per minute usually seen in comparative computer tabulations are only the beginning for these comprehensive articles.

As in many areas of the control field, the decision to rent a new computer is only the first step. Beyond it comes the difficult job of deciding which of the many computers is the right one. Only someone with detailed knowledge can make the latter decision.



The amplifier that beats temperature

NEW DONNER OPERATIONAL AMPLIFIER features exceptionally low drift with temperature variation. (See specs below.) Single channel Model 3811 shown here was tested between −55° C and +55° C in temperature chamber—standard procedure for all Donner amplifiers before delivery.

Drift is *not* a function of temperature in Donner solid state operational amplifiers. Donner's design assures reliable performance at non-constant temperature—as you actually encounter. For only $150, Donner offers a single channel, chopper stabilized amplifier that meets these drift specs (significantly lower per 10° C than any competing model):

DRIFT REFERRED TO INPUT

(a)	at constant temperature:	100 μv/8 hours
(b)	between −20° C and +45° C:	150 μv/10° C
(c)	between −55° C and +55° C:	200 μv/10° C

Donner's operational amplifiers may be used for integration, summation, inversion, differentiation or low-level preamplification. Dual channel units (Model 3811-2) are available on printed cards, priced at $300. Both single and dual channel models use germanium transistors. They are also available with silicon transistors.

OTHER KEY SPECIFICATIONS

Input Impedance, 500k at dc; **Frequency Response,** −3 db at 150 kc (unity closed loop gain); **Open Loop Gain,** 10^6 at dc; **Output Range,** 40 volts. Note: chopper section also solid state.

ORDER NOW IF YOU DESIRE—Donner guarantees all specs and data in this ad. To order, specify Model 3811 Single Channel Operational Amplifier ($150) or Model 3811-2 Dual Channel Amplifier ($300). *Quantity discounts on orders of 10 or more.* Prices are for germanium models, f.o.b. Concord, California. Delivery 45 days.

ADDITIONAL INFORMATION

Technical bulletin gives complete specifications. Also available is new brochure on unique quarter-square multiplier. Please call your Donner rep or write us directly.

DONNER SCIENTIFIC DIVISION

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CONTROL TERMINOLOGY

A Report on U.S. Standards Activity

H. L. MASON
National Bureau of Standards

This report, prepared by the chairman of the American Automatic Control Council's Terminolgy Committee, examines all the present and tentative standards dealing with terms, symbols, and definitions for automatic control loops and their components, including computers.

Several U.S. professional societies have had control systems terminology committees for a decade or more, but control terminology is still in a state of flux. Since January 1956, when the *ASME Transactions* included a review of the situation as of late 1954, both analog and digital computers have become increasingly important to the control engineer. The following survey examines the status of formalized collections of terms, definitions, and symbols for automated computation and actuation developed in the United States. This annotated listing should encourage precision of language, prevent unnecessary duplication of effort, and provide a base for building an international control vocabulary.

The writer would like to thank the many society and organization officials who have provided up-to-date information about their activities.

FOR TERMINOLOGY ON	SEE LISTING UNDER
Components	AIA, AIEE, ASME, ASA, DOD, EIA, FCI, IRE, ISA, JIC, NFPA
Systems	ASME, ASA, EIA, IRE, IRIG, NEMA
Measurement	ASA, ISA, NFPA, SAMA
Digital Computers	AIEE, ASA, ACM
Analog Computers	IRE
For control symbols . . .	. . . see AIEE, ASME, ASA, DOD, IRE, ISA, JIC

AIA

Aerospace Industries Association
Shoreham Building
Washington, D. C.

Specification *NAS 710, Resistors: Variable, Precision*, 1955, includes some 40 definitions relating to design, performance, inspection, and testing.

Standard Gyro Terminology Report EETC-5, prepared by a committee under R. Archibald, provides 76 definitions for categories, types, and performance characteristics.

AIEE

American Institute of Electrical Engineers
33 West 39th St.
New York 18, N. Y.

The AIEE Feedback Control Systems Committee has been represented on the committees for *ASA Y10-14* and *C85*. Its working group on standards, chaired by A. G. Kegel, expects that a report on analog-to-digital converters will be presented for approval soon. Also under review is *AIEE 59-357, Specification Standards for Electrohydraulic Flow Control Servovalves*, by W. J. Thayer, which provides three pages of valve parameter definitions, six of physical specifications, two of performance specifications, and 18 of recommended test procedures, all with illustrations; these standards are compatible with *SAE ARP 490*. Still another being reviewed is *CP 59-467, General Specifications for Ac Tachometers*, by W. E. Sollecito, listing (with four illustrations) the potential errors and ways of measuring them; the AIEE group is maintaining liaison with

SAE's Precision Control Motors group ARP 497.

The Instrumentation Division, under the chairmanship of F. Hamburger, Jr., has had active representation on ASA C42, C39, and C85.

AIEE Transactions Vol. 77, Part I, pp. 429-432, contains the latest definitions approved by the Magnetic Amplifiers Committee, under R. E. Morgan, Subcommittee Chairman.

The Computing Devices Committee sponsored two papers: *Proposed Symbology for Digital Systems*, CP-60-1224, and *Dictionary of Switching Theory Terms: Preliminary Draft*, CP-60-1225.

ASME

American Society of Mechanical Engineers
29 West 39th St.
New York 18, N. Y.

Automatic Control Terminology ASME Std. 105, 1954, is a 15-page glossary evolved from a succession of earlier efforts initiated by the Instruments and Regulators Division. (See *Mechanical Engineering*, March 1944, pp. 205-206; February 1946, pp. 134-138; June 1952, pp. 486-489.) It derives chiefly from usage in the process industries, and much of its content has been carried over into ASA C85. The principal sections relate to controllers, their modes and adjustments, their elements and characteristics, block diagrams and symbols for combination systems, and elements and characteristics of processes.

Preferred Standards for the Presentation of Frequency Response Data, ASME Std. 107, was issued in 1955 by the Instruments and Regulators Division's Dynamic Systems Committee, R. Oldenburger, Chairman. It is a brief document explaining the meaning of magnitude, magnitude ratio, phase angle, and transfer function.

Terminology Chairman J. Stern of the Automatic Controls Division has begun a compilation of terms and definitions for measurement fundamentals, including statistical parameters, which should be completed in 1963. The division has been active in the preparation of ASA C85 and has just submitted for adoption an illustrated *Diaphragm-Actuated Control Valve Terminology* based on ASME 59-A-322, covering physical descriptions of valves and actuators and their functions and characteristics.

ASA

American Standards Association
10 East 40th St.
New York 16, N. Y.

Proposed Terminology for Automatic Controls, ASA C85, is a 90-page alphabetical listing of preferred terms and their definitions, many of which are illustrated. The terms relate to types and components of closed-loop systems, especially idealized linear ones, with their generalized paths, signals, modes, and parameters of control, and graphical and mathematical presentation of performance. Many basic concepts compatible with ASA C39 and ASA C42 are included. In 1955, 22 interested professional societies and trade associations formed a committee, led by Chairman M. A. Princi, in an effort to blend the usages of aeronautical, chemical, electrical, electronic, and mechanical engineers. ASA C85 has been printed by the ASME and was circulated late in April for approval by the sponsors.

Industrial Control Apparatus, ASA C19.1-1943, and AIEE 15-1944, provided definitions, service ratings, and dielectric strength tests for open-loop controls such as rheostats and auto transformers. It is now out of print and is being revised.

Automatic Station Control, Supervisory and Telemetering Equipments, ASA C37.2-1945, applies to the performance and application of devices intended for electric power supply or conversion.

Electrical Indicating Instruments, C39.1-1951 (NEMA EI 1-1959); *Direct Acting Electrical Recording Instruments*, C39.2-1953; and *Automatic Null-Balancing Electrical Measuring Instruments*, C39.4-1956 all cover classifications, definitions, requirements, specifications, and test methods specific to the equipment indicated.

Definitions of Electrical Terms, ASA C42, once a single volume, has been expanded into a series:

C42.10-1957, *Rotating Machinery*
C42.15-1958, *Transformers, Regulators, Reactors and Rectifiers*
C42.20-1956, *Switchgear*
C42.25-1956, *Control Equipment*
C42.30-1957, *Instruments, Meters, and Meter Testing*
C42.35-1957, *Transmission and Distribution*
C42.40-1956, *Transportation*
C42.41-1956, *Transportation—Air*
C42.42-1956, *Transportation—Land*
C42.43-1956, *Transportation—Marine*
C42.45-1959, *Electromechanical Devices*
C42.50-1958, *Electric Welding and Cutting*
C42.55-1956, *Illuminating Engineering*
C42.60-1956, *Electrochemistry and Electrometallurgy*
C42.65-1957, *Communications*
C42.70-1956, *Electron Devices*
C42.80-1957, *Electrobiology including Electrotherapeutics*
C42.85-1956, *Mining*
C42.95-1957, *Miscellaneous*
C42.05, *General Terms*, is in preparation under the chairmanship of J. D. Tebo.

Terminology for Transformers, Regulators, and Reactors, C57.12.80-1958, deals chiefly with the nomenclature of devices and parts.

Sectional Committee X3 on Data Processing Standards, led by H. S. Bright, has a subcommittee responsible for preparing computer nomenclature. It maintains active contact with EIA and with other groups dealing with data processing equipment. Subcommittee X3.6 under V. E. Henriques is concerned with symbols for use in computer flow charts. Subcommittee X3.5 under R. W. Bemer, cooperating with ACM and the International Federation of Information Processing Societies, has developed an 80-column card format and definitions to cover a variety of reference needs. Information on com-

puter data processing available in January, 1961, included 35 source glossaries, about 400 definitions, another 800 terms still to be defined, and some 600 acronym identifications.

Sectional Committee Y14, preparing a Drafting Manual, has a group chaired by R. P. Hoelscher that deals with logic diagrams.

A Proposed Standard for Letter Symbols for Feedback Control Systems, ASA Y10.13, was the result of several years' collaboration between an ASA subcommittee and one from the Feedback Control Systems group of AIEE, and did not seriously conflict with *ASME Std.* 105. Unfortunately, it was necessary to provide definitions for the terms symbolized, and these had not been standardized. As a result, approval of the symbols has been withheld but may follow acceptance of ASA C85.

Graphical Symbols for Fluid Power Diagrams, ASA Y32.10 adopted in 1958, is consistent with the NFPA glossary. Its counterpart in the ASA *Drafting Manual* is Y14.17-1959.

Proposed Graphic Symbols for Logic Diagrams, ASA Y32.14, establishes principles for formation and application of symbols for mathematical and engineering use in digital data processing systems. Definitions of basic binary logical functions are included. The 1960 draft was prepared by representatives from ACM, AIEE, AFCCDD, BuShips, DOD, IRE, and NEMA, under the chairmanship of T. H. Mott, Jr., and has been approved by IRE Committee 21.

Sectional Committee Z39, under the chairmanship of R. E. Kingery, is concerned with library documentation and recently issued ASA Z39.4-1959, *Basic Criteria for Indexes*. One of its subcommittees is studying indexing and coding.

At the suggestion of NEMA and EIA, ASA called an exploratory conference on automation standardization in September 1960. T. E. Veltfort, meeting chairman, was authorized to appoint a small committee which voted in August 1961 to seek a special Standards Council committee to review and redefine, if necessary, the scopes of all committees in the field of "automatic systems".

ACM

Association for Computing Machinery
Room 2814, 420 Lexington Ave.
New York 17, N. Y.

ACM's monthly journal, *Communications*, Vol. 1 (1958), Nos. 6, 8, 9, 10, and 11, serialized the 24-page *Glossary of Computer Engineering and Programming Technology* from *BRL Report* 1010, dated 1957, by M. H. Weik of Aberdeen Proving Ground. It defines radix mathematics, digital computer circuits and devices, programming techniques, and computer operations. Weik's revision of this glossary appears in *BRL Report* 1115, March 1961.

The Standards Committee, with H. S. Bright as chairman, is making a joint effort with groups in AIEE and IRE in the development of a comprehensive glossary of computer terminology.

DOD

Department of Defense
Armed Forces Supply Center
Washington 25, D. C.

Many listings in the *Index of Specifications and Standards* contain glossaries which define types and performance of the equipment they cover, and some include graphical symbols. Although full compatibility with industrial practice is not always achieved, they have been coordinated with the work of professional societies, trade associations, and ASA. Typical of such AFSC and ASESA documents are:

MIL-STD-806A (USAF)	*Graphical Symbols for Logic Diagrams*
MIL-STD-682 (SigC)	*Flow Chart Symbols for Automatic Data Processing Systems*
MIL-STD-12A	*Abbreviations for Use on Drawings*
MIL-STD-15A	*Electrical and Electronic Symbols*
MIL-E-1	*Specifications on Electron Tubes*
MIL-S-19500	*Specifications on Semiconductor Devices*
MIL-S-20708	*Synchros*

Similar coverage is expected by 1962 for devices such as servomotors, resolvers (data transmitting types, computing types), and tachometer generators.

EIA

Electronic Industries Association
650 Salmon Tower, 11 West 42nd St.
New York 36, N. Y.

Analog-to-Digital Conversion Equipment, Standards Proposal No. 651, which defines three basic methods and lists essential specifications, has been referred to the EIA General Standards Committee.

Definitions for Numerically Controlled Machine Tools, Including Machine Axis Nomenclature was prepared in 1958 by Committee A-6.1 and includes about 40 items in analog and digital usage. EIA terminology can eventually be expected from committees on Automation Systems, Numerical Machine Tool Control Standards, Continuous Process Control Equipment, Data Transmission Equipment, Storage Media and Language, Computers, and Computer Data Processing.

FCI

Fluid Controls Institute
1075 Lincoln Ave.
Hamilton, Ohio

Three standards pertaining to actuating devices in fluid systems have been prepared by committees headed by N. Belaef. *FCI* 55-1 classifies power actuated valves and their parts, *FCI* 58-1 provides methods for expressing capacities of self actuating regulators, and *FCI* 58-2 recommends a procedure

for testing flow capacity. Standards for solenoid valves and for steam traps are expected in late 1961.

IRE

Institute of Radio Engineers
1 East 79th St.
New York 21, N. Y.

The Feedback Controls Committee, G. S. Axelby, Chairman, has published standards on symbols and terminology as *IRE* 26.S1 (*Proc. IRE*, November 1955) and *IRE* 26.S2 (*Proc. IRE*, January 1956). Also, 25 tentative definitions were published in the *IRE-PGAC* Transactions of March 1958. *IRE* 26.S1 defines about 35 generalized terms for signals, paths, transfer functions, and system types. *IRE* 7.S1, *Definitions of Terms Related to Storage Tubes*, 1956, contains 25 items applicable to electron tubes that retain information on a charged surface. A reactivated group met recently to plan to work on control system measurement.

Proposed Standard Definitions, Abbreviations and Symbols for Analog Computers, 60 *IRE* 8.8 PS1, covers the functions, component units, and operations in analog computing. Chairman C. D. Morrill has sent the 39-page document to the Electronic Computers Committee, IRE 8, and the Symbols Committee, IRE 21, for review.

ISA

Instrument Society of America
313 Sixth Ave.
Pittsburgh 22, Pa.

Instrument Flow Plan Symbols RP 5.1 recommends graphical standards with mnemonic letter designations for the elements of a piping or wiring system. It includes measuring and controlling devices commonly used in process industries.

Dynamic Response Testing of Process Control Instrumentation, RP 26.1-1957, is a tentative recommended standard for testing, test equipment, and data presentation, prepared by F. H. Winterkamp's Committee *RP*-26. A short illustrative glossary is included. *RP*26.2-1960 and *RP*26.3-1960 provide further details for pneumatic and electric outputs.

The Aerospace Standards Division has a group 8A-*RP* 28, chaired by A. C. Plantz, which has recommended the *AIA Gyro Terminology EETC*-5 as ISA standard. Subcommittee 8A-RP 30, under co-chairmen E. C. Spencer and L. Fleming, is preparing an ISA standard based on *AIA-ARTC Report 16, Glossary of Terms for Flight Test Instrumentation* (1957). A project committee on flow measurement, with R. L. Galley as chairman, is completing the format of tentative *RP* 31.1, *Technology and Specifications for Turbine Type Flow Transducers*. A survey committee 8A-RP 37, with H. H. Norton as chairman, is planning a definitive nomenclature for transducers used in aerospace testing.

IRIG

Secretariat
Inter-Range Instrumentation Group
White Sands Missile Range, New Mexico.

Telemetry Standards IRIG 106-60 contains a 16-page glossary covering information theory, inter-range operating practices, analog and digital signals, system hardware, and acronyms.

JIC

Joint Industry Conference
Prod. Engr. Sec., General Motors Corp.
3044 W. Grand Blvd., Detroit 32, Mich.

Hydraulic Standards for Industrial Equipment (1959) supplies specifications for the application of hydraulic apparatus, including controls, used in manufacturing processes. The graphical symbols listed are those of ASA Y32.10.

NEMA

National Electrical Manufacturers Association
155 East 44th St.
New York 17, N. Y.

The Industrial Automatic Systems Section, R. W. Shaul, Secretary, has an active Subcommittee on Definitions chaired by R. N. Eck. In the category of feedback control systems, about 90 definitions, some of specific circuit functions, but most covering generalized concepts like those of ASA C85, have been approved as NEMA standards. The committee is now turning its main attention to industrial computer systems.

NFPA

National Fluid Power Association
5595 North Hollywood Ave.
Milwaukee 17, Wis.

Glossary of Terms for Fluid Power, 2nd Ed., 1960, is an interim document prepared by representatives of hydraulic and pneumatic industries, chaired by W. J. Kudlaty. Its 27 pages collate terms and definitions related to flow and its measurement and to pumps and compressors and their mechanical parts. NFPA's interest in graphical symbols is met by ASA Y14.17-1959 and Y32.10-1958.

SAMA

Scientific Apparatus Makers Association
370 Lexington Ave.
New York 17, N. Y.

*Accuracy and Sensitivity Terminology as Applied to Industrial Instruments, RC*3-12-1955, discusses ways of expressing and measuring the concepts in the title. Brief glossaries in other publications cover chart drives and controller air pressures.

Controlling a Missile by Swiveling the Rocket Motor

In an attempt to prove missile capabilities, Chance Vought evolved this uniquely controlled vehicle in 182 days—from initial concept to first flight test. With a requirement in mind for a short but variable range, inexpensive surface-to-surface missile, a design was reached which involved a small, solid fueled vehicle with a swivelable rocket motor for the necessary short range maneuverability. Author Meyer tells how this new concept was developed within so short a time—using off the shelf components and fast decisions—culminating in a successful first flight.

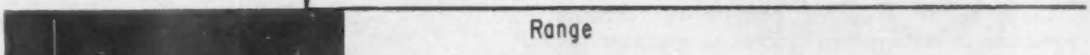


FIG. 2. Mission profile shows how trajectory control and attitude stabilization are important to get maneuverability over the short range.

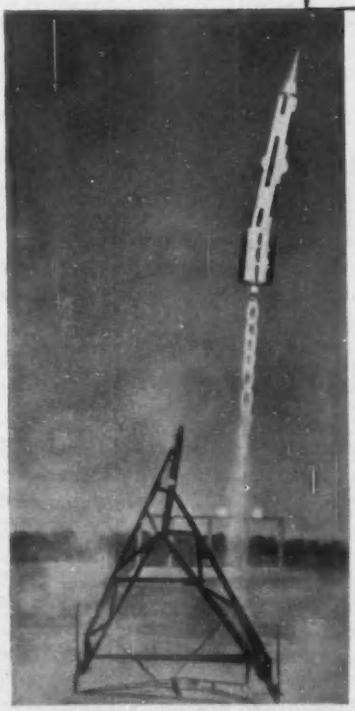


FIG. 1. Firing of the articulated missile shows swiveling rocket motor being used to program vehicle into more horizontal trajectory. Launcher is simple rail design constructed for the flight test program.

L. L. MEYER,* Chance Vought Corp.

The control system of this unusual missile, Figure 1, was called upon to provide two functions: trajectory control for the desired mission profile as ordered by trajectory instructions, and dynamic attitude stabilization. These functions are shown in Figure 2. Because of the relatively short range and low cost requirements, the swiveled rocket motor concept was decided on for thrust vector control from a zero velocity launch and for maneuverability. Low aspect ratio fins were added for simultaneous aerodynamic and thrust vector control in pitch and yaw during burning and for aerodynamic control after burnout. Relative motion between the forward missile body and the rocket motor section was controlled at a universal joint by electrohydraulic actuators.

As a demonstration of rocket missile capabilities and to prove the unique design, Chance Vought underwrote a program to design, build, and flight test six missiles in 180 days. As a company sponsored project, the budget limitations were relatively tight. Because of this short development period and the new concept of control, it was required to select hardware early and plan for extensive system tests. Gyros, servovalves, actuators, and hydraulic power

* Deceased

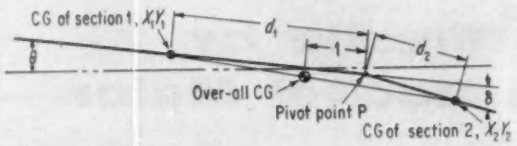


FIG. 3. Mass distributions used in power control loop analysis.

elements had to be chosen based on preliminary missile characteristics and system requirements—well weighted by educated guesses. Flexibility for later changes was retained, however. The fabrication of a missile simulator was also started early.

Aerodynamic characteristics

Initial design was based on a 12-in. diam cylindrical missile with a conical nose section. Final length and rocket motor size envolved from the space and weight requirements of the missile components. The vehicle was designed to be symmetrical in two planes; i.e., the pitch and yaw systems were basically identical. Also, for zero rocket deflection, all products of inertia were zero. Because of this symmetry, all linearized analysis performed for the pitch system was assumed applicable for yaw.

Conventional linearized perturbation airframe equations of motion were written to represent the dynamic behavior of the missile in flight. Aerodynamic coefficients for these equations were obtained from a low speed wind tunnel test combined with theoretical data. Trajectory analysis provided information for selection of critical flight conditions, and evolution of the design provided weight and balance information. These data combined in the airframe equations of motion resulted in transfer functions of the vehicle in the dynamic system. Preliminary control system characteristics were chosen and combined with these transfer functions in the form of root locus plots of a rigid body plus servosystem characteristics. Various sets of flight conditions, including variations in missile static stability margins, were investigated with several different closed-loop servosystem dynamic characteristics. Results showed detrimental effects of undamped airframe open-loop zeros which resulted in relatively high closed-loop frequencies of the rigid body short-period mode. The high frequency short-period mode indicated that a high frequency response, well damped servosystem was required.

Before the preliminary closed-loop rigid body systems analysis could be made, it was necessary to select rate gyros for the pitch and yaw stabilization channels. At the time, it was estimated that a structural natural frequency on the order of 25 cps would exist at the universal joint. Rate gyros available off the shelf, that were compatible with the system's angular rate requirements, had natural frequencies of 14 and 27 cps at nominal damping factors of 0.4-0.7. To minimize possible gyro structural resonance problems, the 14-cps gyro was selected. Even this gyro could result in problems when used with a high frequency response servosystem, but before pursuing this it was decided to pin down possible servosystem characteristics and structural elasticity effects at the universal joint.

Power control

The minor (power control) loop in the pitch and yaw systems was the first to be analyzed in detail. Because of the size of the masses involved, it was necessary to make a detailed study of their effects. Figure 3 shows the mass relationships used.

There are two cases that must be investigated. The first case is that of the missile on a launcher with the forward section restrained. For this the effective total moment of inertia about the total center of gravity (I_{eff}) is equal to the moment of inertia of the rocket motor about the pivot point ($\bar{I}_2$). For the second case, the missile in free flight, the analysis is more complex but gives

$$I_{eff}\frac{d\delta}{dt} + K\delta = 0 \tag{1}$$

where K is the value of the spring restraint of the system. From this can be found

$$\omega_n = \sqrt{\frac{KR^2}{I_{eff}}} \tag{2}$$

where R is the moment arm for K and

$$I_{eff} = \bar{I}_2 - \frac{(m_2 d_2)^2}{m} - \frac{(\bar{I}_2 + m_2 d_{21})^2}{I} \tag{3}$$

From calculated and measured data it was found that $I_{eff} = 5.25$ slug-ft² for the missile in free flight immediately after launch. Also, $K = K_{eq} = 822{,}000$ lb/ft, the equivalent spring which is the resultant of outside-the-loop and inside-the-loop springs in series; $R = 5$ in., the distance between an actuator and the universal joint; and

$$\omega_n = \sqrt{\frac{822{,}000\ (0.416)^2}{5.25}} = 164.5 \text{ rad/sec} = 26.2 \text{ cps}$$

The missile simulator with design mass and structural stiffness was used to check these analytical results. The control actuators and servovalves used on the simulator were the same as those intended for use in the flight test vehicle so that comparable system dynamics could be observed.

It was necessary to design a servoamplifier for the simulator to test the closed-loop performance. An amplifier gain control was designed into the amplifier so that system gain could be varied during the tests. The power control servo loop is shown in Figure 4; the simulator, in Figure 5. It was supported by long cables to simulate the dynamics of the missile in free flight. All frequency response runs were made in the yaw system to minimize the effects of cable dynamics. This cable jig was later used to check out each missile after fabrication.

Open-loop yaw power control data taken from the

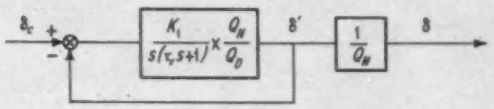


FIG. 4. Power control servo loop in which Q_N, Q_D represents quadratic equations in s involving ω_1, ω_n, and δ_1. ω_n is given by Equation 2 with K being K_{ee}. ω_1 is the same with K being K_s, the outside-the-loop spring. K_1 of the loop is the product of the gain of the summing network, the amplifier gain, the follow-up potentiometer gain, and the servovalve gain, divided by the actuator area. τ_v is the valve time constant.

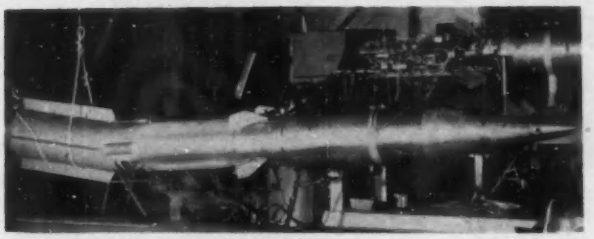


FIG. 5. Cable supported missile simulator uncovered dual resonance problem in the missile system. It was also used to check actual missiles.

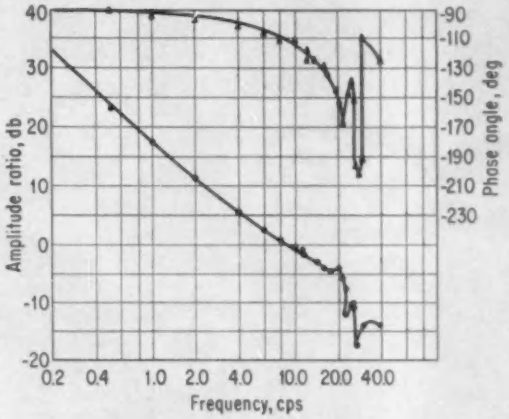


FIG. 6. Yaw channel response data obtained on the simulator shown in Figure 5.

simulator is given in Figure 6. It can be seen that there were actually two resonant frequencies, rather than the single one that had been expected. A close examination showed that this lower frequency resonance occurred about an axis that was parallel to a line connecting the two actuators. The higher frequency response occurred about an axis perpendicular to a line between the two actuators.

The finding of the second resonance emphasizes the importance of these tests. After the fact, it is seen that the minimum resonant frequency will occur at the minimum spring moment arm if the values for K and I_{off} are correct and that the minimum arm is not the distance between the actuator and the pivot. The detailed analysis of the dual resonance problem will not be followed here; it will suffice to note that the analysis carried out agreed quite well with the actual data of Figure 6. In the analysis it was found to be a valid simplification to consider the lower frequency resonant mode only. Based on servosystem design and tests, and from the results of the rigid body system analysis, a tentative minor loop gain of 62 was selected; this produced a well damped 20-cps system.

Final stabilized system

The next step was to refine and expand the basic system analysis. Figure 7 shows the functional relationship of the system components and control loops. The dynamic performance of the rate gyro is characterized by the second order expression

$$\frac{d\theta_i/dt}{d\theta/dt} = \frac{\omega_g^2}{s^2 + 2\,\zeta_g\,\omega_g s + \omega_g^2} \tag{4}$$

where $\omega_g = 14$ cps, $\zeta_g = 0.7$ and $\theta_i/\theta = 1$. The inner-loop transfer function becomes simply

$$\frac{\delta_e}{\delta_{ec}} = \frac{K_1}{s\,(\tau_v s + 1)\,Q_D + K_1 Q_N} \tag{5}$$

which can be written as

$$\frac{\delta_e}{\delta_{ec}} = \frac{\omega_e^2}{s^2 + 2\zeta\omega_e s + \omega_e^2} \times \frac{(\omega_D)^2}{s^2 + 2\zeta\omega_D + \omega_D^2} \tag{6}$$

in which the second resonant mode in Q_N/Q_D is neglected. The ω's and ζ's in the above expression were obtained from root locus plots.

A relatively large number of flight conditions were investigated throughout the rigid body analysis, from which it was concluded that a launch (zero velocity) condition and a rocket burnout (maximum dynamic pressure) flight condition encompassed the full range of critical flight. Airframe transfer functions (airframe phugoid mode neglected) were

$$\frac{\theta}{\delta_e} = \frac{176\,s^2 + 19.6}{s^2} \qquad \text{(launch)} \tag{7}$$

$$\frac{\theta}{\delta_e} = \frac{0.148\,s^2 + 163.8}{s^2 + 0.97 + 11.7} \qquad \text{(burnout)} \tag{8}$$

These transfer functions represent the final selection of aerodynamic static margin.

Complete system analysis

The elements of the complete system were combined, as they evolved, on a root locus plot for a

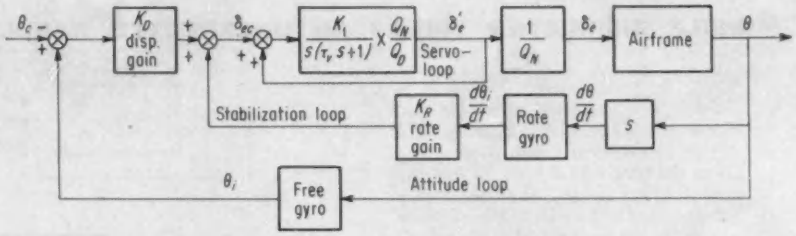


FIG. 7. Functional diagram of the entire control system.

complete system dynamics picture. Addition of the structural mode and rate gyro dynamics to the analysis, combined with the high performance (20-cps) servosystem, caused vehicle and control instability due to the structural mode at a very low value of attitude gain. A conventional solution to structural resonance problems is to install a passive notch filter in the stabilization loop, thus preventing a structural feedback. But variation in missile mass during burning, causing a change in resonant frequency, would decrease the notch filter method's effectiveness enough that it seemed necessary to look for another method of attenuation.

An attempt was made to obtain better structural damping by decreasing the gain of the power control loop. This resulted in two real closed-loop poles, one of which approached the origin as gain was decreased. The lower servo gain aided the structural problem but prevented adequate stabilization of the rigid body mode. To overcome this it was reasoned that, if the primary closed-loop poles could be reduced in frequency with only moderate damping, the airframe response could be maintained with structural attenuation obtained by the lowered frequency poles. This was done by adding a 0.18-microfarad capacitor between the plates of the first stage servoamplifier tubes, a relatively minor modification. This change resulted in a lag network with a break frequency at 25 rad per sec in the forward path of the servo loop. With a servo loop gain of 44 selected, primary mode closed-loop poles on a newly plotted root locus diagram showed a 30-percent damping, with a natural frequency of about 5 cps. A substantial improvement in total system performance was realized; structural mode was made more stable with increasing gain; ample attitude loop gain and airframe damping were available.

To attain a gain margin of 6 db, a maximum design gain of 0.31 for the burnout flight condition was found necessary. For the launch condition, the desirability of higher gain to improve airframe short period damping led to the choice of 0.67 for this condition's maximum design gain, roughly twice that for the burnout condition. The final analysis indicated that the relatively poor damping at very low frequency just following missile launch, which would result from using a constant gain throughout the flight trajectory, would exist for a very short time. As vehicle airspeed increased, short period damping and frequency would increase such that the poorly damped mode of motion at launch could only exist for about one or two cycles. The conclusion of the analysis, then, was to design the system for constant rate and displacement gains in the pitch and yaw channels for the entire flight.

An interesting sidelight to the control system analysis was provided by replacing the rate gyros in the system by rate networks. The use of rate networks allowed a larger margin for tailoring root locus poles and zeros to match system performance requirements. The free gryo potentiometer pickoffs did contribute a resolution problem when rate networks were added, which was deemed inconsequential but somewhat disconcerting. The rate networks were not flown in the flight test program, but the studies conducted demonstrated the feasibility of obtaining improved performance, lower costs, and better reliability by using the rate networks in place of the rate gyros.

The missile completed—and flown

The missile stabilization system as finally constructed consisted of identical components in the yaw and pitch channels. These were: a displacement gyro, a rate gyro, an amplifier, and an electrohydraulic servosystem. The roll control channel used the inner gimbal pickoff of the yaw displacement gyro for attitude reference and, instead of a rate gyro, a rate network was used for damping. A servoamplifier and electrohydraulic servosystem driving a spider linkage to four roll surfaces completed the roll control system. The desirability of high roll system gain at launch to maintain roll attitude to as near as possible during launch, combined with the necessity of low gain at high dynamic pressure, required a gain-changing device in the roll channel. This was provided by a pot driven by a pitch programmer that supplied the proper roll system gain as a function of time. A pitch programmer, a clock positioned variable resistor, created a pitch program for mission profile control. The pitch program and associated desired missile range for a specific flight were selected by a potentiometer adjustment. Electrical power was from a battery.

Five complete missiles were built for the flight test series. The first missile was flown 182 days from the start of the program. Four of the five were considered to be completely successful flights.

THE GIST: In a counting application that requires cross totals of many counts or sorting of numerous different totals, computer techniques can be more economical than traditional electromechanical counters. Computer techniques become economical when the number of required counters passes 100. A magnetic drum stores the accumulated totals just as a counter register would; simple logic circuits perform the actual counting. In variations to this basic system, the memory can count down to zero, can compare totals to preset numbers, or can add at rates up to 7,680 counts per sec. For example a magnetic drum counting system can keep track of tolls paid at up to 50 lanes of a facility which also wants to total 13 different kinds of vehicle paying the tolls.

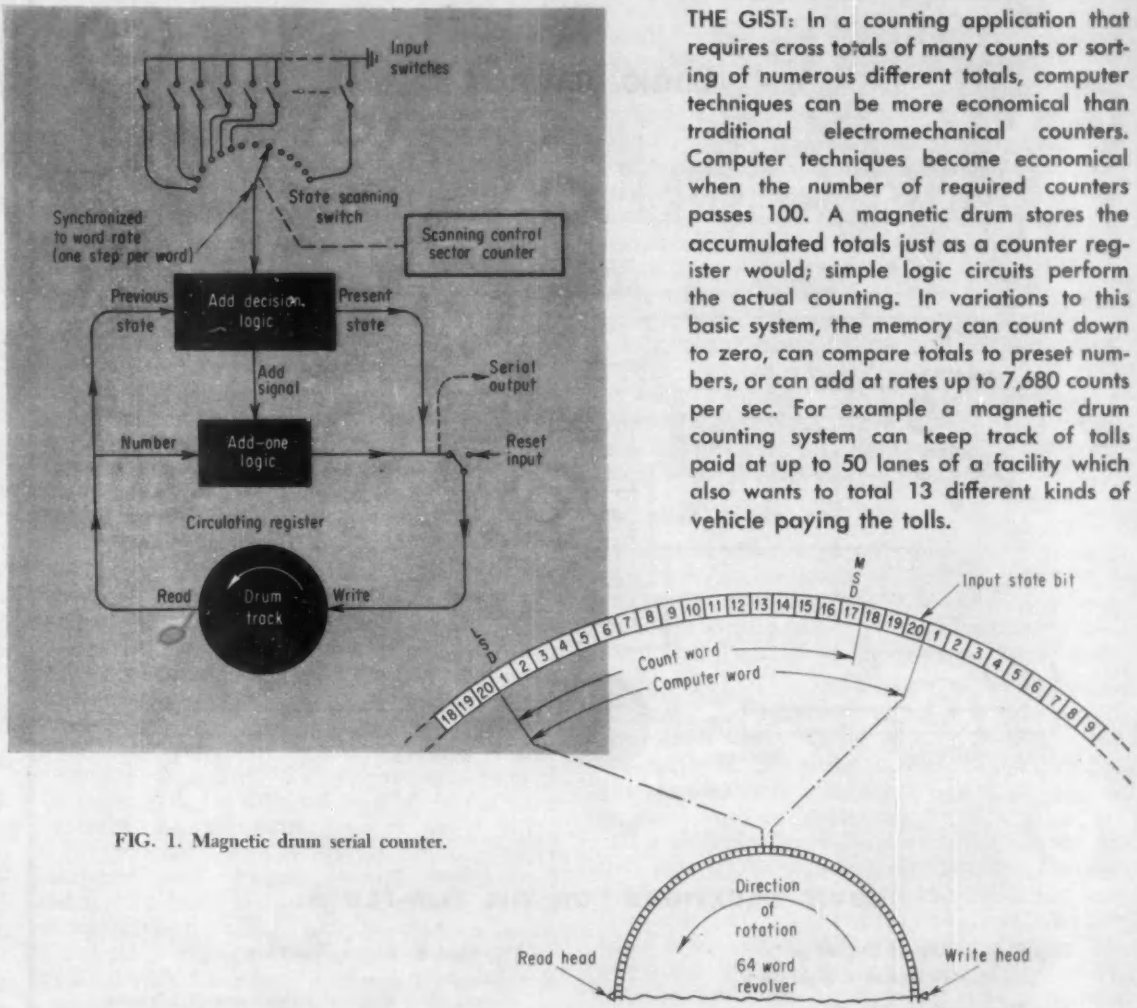


FIG. 1. Magnetic drum serial counter.

COUNTING on a Magnetic Drum

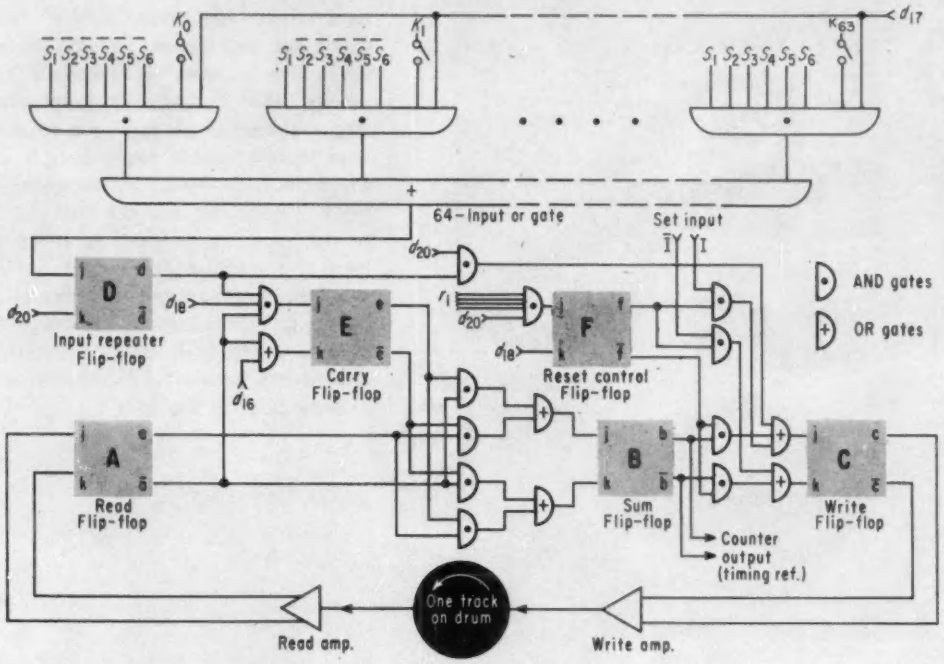
M. E. FRANK and S. T. SCHY
TRW Computers Co.

In an automobile manufacturing plant that makes cars in 10 different colors, the production control department needs to know how many red fenders have been produced, how many blue ones, how many green ones, and how many of every other color. And the department needs the same kind of count for about 20 other key parts. In all, the plant might require over 200 counters.

The problem of maintaining so many assorted totals sounds like other problems that have been solved by a computer. The operation of counting by unity is a degenerate form of adding two numbers. And the requirement for sorting the accumulated counts in a number of counter registers is equivalent to the storage requirement of a digital computer. Thus a large number of counters can be provided by a single magnetic drum counting system, composed of a computer-type memory with enough capacity to store the required counts and a form of adder to carry out the counting functions.

A typical small magnetic drum, the least expen-

LOGIC DIAGRAM



LOGIC EQUATIONS FOR THE FLIP-FLOPS:

Flip-Flop A—Read Flip-Flop

Reproduces contents of drum track

Flip-Flop B—Sum Flip-Flop

$J_B = A\overline{E} + \overline{A}E$
(sum "one" inputs)
$K_B = AE + \overline{A}\overline{E}$
(sum "zero" inputs)

Flip-Flop C—Write Flip-Flop

$J_c = B\overline{F}$ (copy sum) $+ IF$ (copy external input) $+ D\,d_{20}$ (record switch state)
$K_c = \overline{B}\overline{F}$ (copy sum) $+ \overline{I}F$ (copy external input)

Flip-Flop D—Input Repeater

$J_D = \overline{S}_1\,\overline{S}_2\,\overline{S}_3\,\overline{S}_4\,\overline{S}_5\,\overline{S}_6\,d_{17}\,K_0 +$
$S_1\,\overline{S}_2\,\overline{S}_3\,\overline{S}_4\,\overline{S}_5\,\overline{S}_6\,d_{17}\,K_1 + \cdots$
$S_1\,S_2\,S_3\,S_4\,S_5\,S_6\,d_{17}\,K_{63}$
(input from input switch scanning gates)
$K_D = d_{20}$
(resets flip-flop D)

Flip-Flop E—Carry Flip-Flop

$J_E = \overline{A}D\,d_{18}$
(sets carry flip-flop if input switch is closed and if recorded indication bit shows it was not closed last revolution)
$K_E = \overline{A}$ (carry term of add one logic) $+ D_{16}$ (reset in case of overflow)

Flip-Flop F—Reset Control

$J_F = R_i\,d_{20}$
(external input order)
$K_F = d_{18}$
(termination of external input)

Noet:
Read Equation $J_B = A\overline{E} + \overline{A}E$ as the J input to flip-flop B is A AND NOT E OR NOT A AND E.

Figure 2.

sive memory in digital computers, can store many thousands of words, each of which can represent a counter storage register. In one such system (described below) the magnetic drum contains 64 counter registers on each of 50 to 100 tracks. That means 3,200 to 6,400 counters on a small drum that costs about $10,000. One logic arrangement for counting is shared by all the counters.

Figure 1 shows the basic logic of the magnetic-drum counter. Important functional parts are: the drum; add-one logic that performs the counting; and add-decision logic that decides whether to count.

Words that represent counts are stored in a circulating register. Numbers are read from the drum, circulated through the add-one logic, and rerecorded on the drum. Ordinarily, the number read is rerecorded without change. A change is made—one count is added—only if the add-decision logic detects the need for it in any particular word. The words pass through the add-one logic at a rate set by the speed of drum rotation.

Whether a count is added or not depends on the condition of the input switches. As the words pass through the add-one logic, the state scanning switch advances in synchronism so that each input switch is associated with a particular word on the drum. If the add-decision logic finds a closed switch that was open the last time the associated word was circulated, the add-one logic is activated, causing a count to be added. The previous condition of the input switch is indicated by a bit in the word associated with that switch.

The add-one operation can be implemented a number of ways. In one approach, regular serial addition logic is set up so the circulating word is one input and a single pulse at the least significant digit time is the other. The same result can be obtained with fewer logic elements, using what is essentially an add circuit with only one input. In this arrangement, the carry flip-flop is forced to the "carry" state one bit time before the least significant digit time. If a conventional serial add circuit is modified to retain only those components required by the single number input and carry, it will follow this rule for adding one to a binary number:

> *Starting at the least-significant-digit end, change all ONE's to ZERO's until the first ZERO is encountered. Change that ZERO to a ONE and copy the remainder of the number unchanged.*

In most applications for a multiple input counter system, the counts to be accumulated originate as contact closures that occur randomly on each of a number of input lines. If, for example, inputs are to be accepted from 64 counter input lines, the accumulation from each input line will be stored in one of 64 sectors of a recirculating register made up of one track of a magnetic drum. Each register will be identified as a word of 20 bits: 17 bits represent the magnitude of the count and the remaining three (bits 18, 19 and 20) are for control.

Such a system, whose main components are six flip-flops, is described in Figure 2, along with the logic equations. Timing pulses generated into the system play an important role in its operation. For example, when start pulse d_1* is generated, the least significant bit of the count is at the output of the *sum* flip-flop and the input of the *write* flip-flop. When pulse d_{17} is generated, the most significant bit is at that point. Timing pulses d_{18} and d_{20} start other important parts of the counting operation.

In this configuration, if the *read* and *write* heads are 180 deg apart, a basic 120 word track will yield 64 words of memory. More precisely, the distance between the *write* and *read* heads is 3 bit positions less than 64 words, with the remaining 3 bits being stored in the external logic of the revolver.

Counter Logic

Counting action starts with an input signal from relay or switch contacts K_0, K_1 ... K_{63}, which close and remain closed for more than two revolver revolutions to record a count. A sector counter synchronized to the rotation of the drum generates signals S_1, S_2, S_3, S_4, S_5, S_6 and their complements $\bar{S}_1$, $\bar{S}_2$, $\bar{S}_3$, $\bar{S}_4$, $\bar{S}_5$, $\bar{S}_6$ to actuate the scanning gates which sequentially switch the signals from the input contacts to the *input repeater* flip-flop (D) (Figure 2). This scanning action associates each input with a particular word in the revolver.

If a particular input contact has just closed, the true state of the *input repeater* flip-flop (D) and the false state of *read* flip-flop (A), indicating that the contact was not closed last revolution, are combined in the J-input AND gate setting it true. This action sets the carry flip-flop to true state one bit time before the least-significant-bit time of a word. Because of delay in flip-flops (E) and (B), d_{18} time at the input to (E) is equivalent to d_{20} time at the reference point, the output of flip-flop (B).

The carry flip-flop remains in the true state as long as the incoming word from the revolver is a series of one's. At the occurrence of the first zero, the carry flip-flop is set back to false. The output of the carry flip-flop actuates input gates to the sum flip-flop (B) inverting the bits of the previously recorded word.

At the same time that the counting action is taking place, the state of the *input* repeater is being

Pulse times are indicated by d numbers in this article. They represent relative times and relative positions. The output of the flip-flop (B) is chosen as the reference point. At this point, the time numbers are equivalent to digit positions on the drum. First digit in a word generates a pulse at d time; the 20th digit position on drum generates a pulse at d_{20} time, etc. Because of the one-bit delay in flip-flops, digit 20 position is equivalent to a pulse time d_{19} at the input of flip-flop (B), d_{18} at input to flip-flop (A).

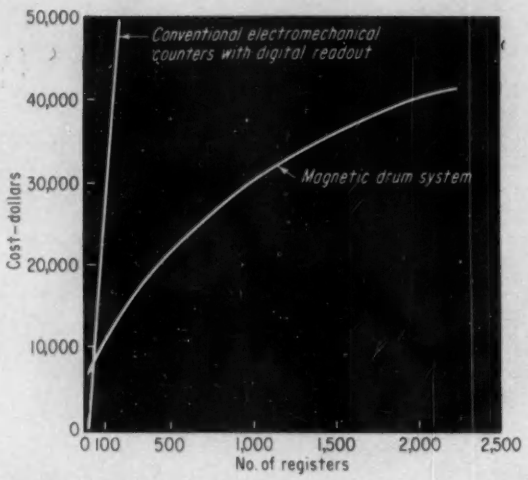


FIG. 3. Comparison of hardware costs for electromechanical counter and a magnetic drum system.

recorded into bit 20 position of the word. This bit will indicate the current state of the particular input during the next revolution of the revolver. This bit is recorded every revolution whether or not a count is recorded. It insures that only one count is recorded for each closure.

After one contact has been inspected, the *input repeater* is reset by d_{20} to prepare for another input and the *carry* flip-flop is reset by d_{18} to prevent over-flow from one word into the next word.

A *reset control* flip-flop (F) can reset the contents of the register to zero or set it to any predetermined number. The signals of the *J*-input of this flip-flop (F), shown as R_t designate the word to be reset. The number enters at the point marked "set input."

The diagram of Figure 2 illustrates the principle of the serial counter with a particular type of logic; different configurations could serve the same purposes. In particular, the illustration uses more flip-flops than are required for logic.

For example, if the counter need not be reset, flip-flop F could be taken out. In computer applications, reset might not be needed since the computer can take differences between successive readings. Alternatively, the outputs required from flip-flop F might be available from a flip-flop which serves other purposes in the computer control.

The inputs to flip-flop B could go directly into the *write* flip-flop C. The extra flip-flop allows counter input and output with the same timing and with the output containing the latest count. If reset capability is not required, or if input and output with different digit timing can be tolerated, the functions of flip-flop B and C can be combined. In a similar fashion, one flip-flop could serve the functions of D and E. Flip-flop D serves a circuit function, not a logic function; it acts as a buffer between the 64-input OR gate and the other logic.

In a practical circuit, the 64-input OR might have to be broken down even further. For example, four 16-input OR gates might actuate four flip-flops. The output of these flip-flops would in turn be ORed together to provide the input to the *J* input AND gate of flip-flop E.

Only one flip-flop besides the *read* and *write* flip-flops is required for the add-one function. The others are required because of circuit considerations or add to the counter's input-output facility.

Variations

From this basic system of logic many variations and alternative configurations are possible:

1) Faster counting rate

The 64 word per track arrangement is only one of several configurations that could be applied to a typical magnetic drum. For a 3,600 rpm drum, the 64 word revolver on a 128 word track can count at rates up to 120 per sec. Similarly, if the read and write heads are located one-fourth the total track length apart, a 32 word revolver is produced, allowing counting rates up to 240 per sec.

A one word revolver could add at a rate of 7,680 counts per sec. Because of the serial nature of the equipment, the number of possible registers can always be traded for speed. The number of registers can be increased by using more than one track; typical magnetic drums may have as many as 60 tracks. The logic can be performed with separate circuitry for each track on the drum or with common circuitry time shared by a head switching matrix. In the latter case, of course, the counting rate would be decreased by a factor equal to the total number of tracks.

In many applications this scheme is quite practical. For example, in the toll bridge data collecting system discussed on page 79, counts are generated at a rate no greater than one every 2 sec. Therefore, with a single track capable of counting at a rate of 120 counts per sec, as many as 240 tracks could share the same counter logic. The total number of registers available then would be 15,360—far more than needed in an actual application.

2) Other codes

The system as described relies on the binary system to accumulate counts. This code is the most compatible with many digital computers and requires the least expensive logic systems. Binary coded decimal in any desired code configuration, however, could be implemented using the same philosophy.

3) Subtraction

Subtraction can be achieved with the same amount of equipment as required for addition. A small extra amount of logic provides subtraction in the registers along with addition. Subtracting counters could be useful in such areas as production control where it is desirable to know when a predetermined count has been reached. The desired count is entered in a register and a signal generated when the contents of the register reach zero.

4) Comparison

Additional logic can be added to provide for continuous comparison of the number in the register with a predetermined number in an adjacent memory location. The output: the difference between the accumulated count and the desired number.

Economic advantages

The cost advantage of the magnetic drum system is determined largely by the total number of counters required and how the data derived from the counters is to be used. In general, for systems with less than 100 counters, conventional counters are cheaper because there is a high fixed cost associated with magnetic drums and logic circuitry.

Figure 3 shows the relative costs of magnetic drum and electromagnetic counter systems. The magnetic drum equipment would have a first cost approximating $10,000 for a basic system with 100 counter registers. The cost of a 1,000-register system would be in the $30,000 range; however, the curve begins to level out above this point. For example, to supply an additional 1,000 registers would cost only another $10,000. By contrast, the cost of conventional electromechanical counters rises linearly.

These curves were drawn for hardware costs only and do not include installation. The cost of wiring a parallel digital output of the electromechanical counters would be many times that of installing a magnetic drum system.

One other advantage of the magnetic drum system is reliability. The small number of parts, many of which are solid state static switching elements, provide reliability on the order of 99.9 percent—something not attainable with conventional electromechanical counters. Redundancy through duplicated registers in adjacent tracks—or on separate drums—is possible at relatively low cost per counter register.

Gathering Toll Gate Data with a Magnetic Drum Counting System

A large tolls collecting facility can have as many as 50 lanes in which tolls are collected. Different tolls are collected for different types of vehicles. At the end of the day, the accounting department has to correlate the amount of money taken in by a particular collector with the vehicle count in the lanes he has worked.

A treadle switch in each lane closes whenever the wheel of a vehicle passes over it, thus supplying the axle count. The toll collector has a keyboard with 13 push buttons representing the 13 different classifications of vehicle recognized at the tolls facility.

Formerly, electromechanical printing counters in a central location made these counts. Each lane needs one counter for each classification and one for the axle count—14 counters per lane. These counters are arranged in a single line so that upon command a print can be made of the total count in all 14 registers. In addition, a numerical printing register is provided for the toll collector's identification number and another register for time of day. The total printout, therefore, consists of 16 columns of information. A printout is initiated when a new collector comes on duty and when he leaves. When the collector inserts an identifying key into a slot at the toll booth he initiates the printout. The key number is recorded in the collector's I.D. number register. A demand print can also be initiated by the tolls sergeant in charge of operations.

At the end of a day, the printed record of operation at one lane shows two lines of data for each collector who has worked that lane. The first line represents the status of the counter registers when he came on duty; the second line that status when he leaves. In order to collate the data relating to each collector the printed record has to be cut apart and the strips sorted by collector number. Operators with adding machines can then determine the total number of vehicles handled in each classification by each collector, as well as the total of axles counted.

Axle count alone cannot be correlated with tolls collected, since different tolls may be collected for a passenger car or a pick-up truck. However, axle count can be correlated with classification, since the classification implies a particular number of axles, as well as a particular toll amount.

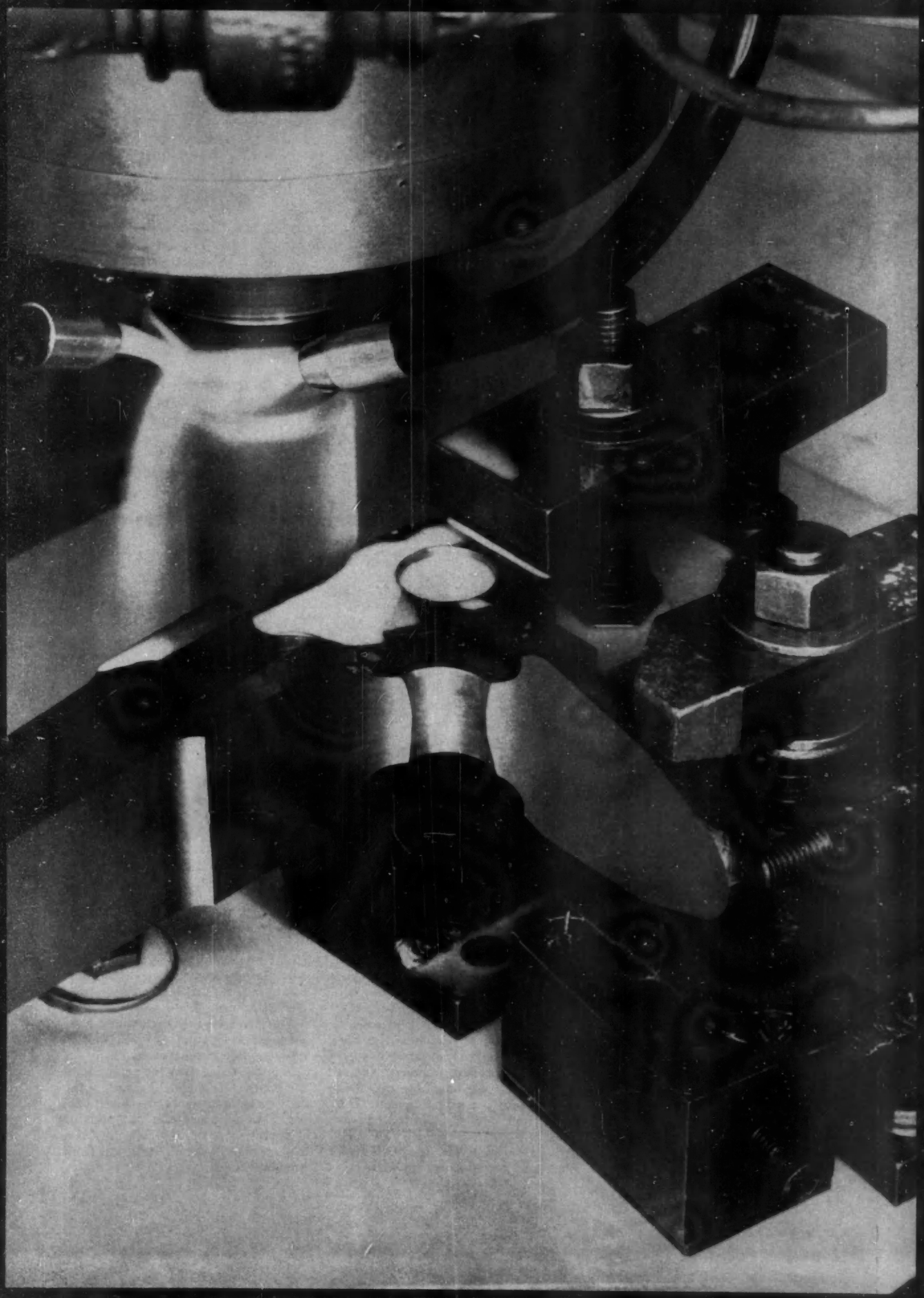
Next, the data are prepared for analysis in a digital computer. Data from the printed records are prepared by keypunch operators on punched cards which are then automatically collated prior to entry to the computer.

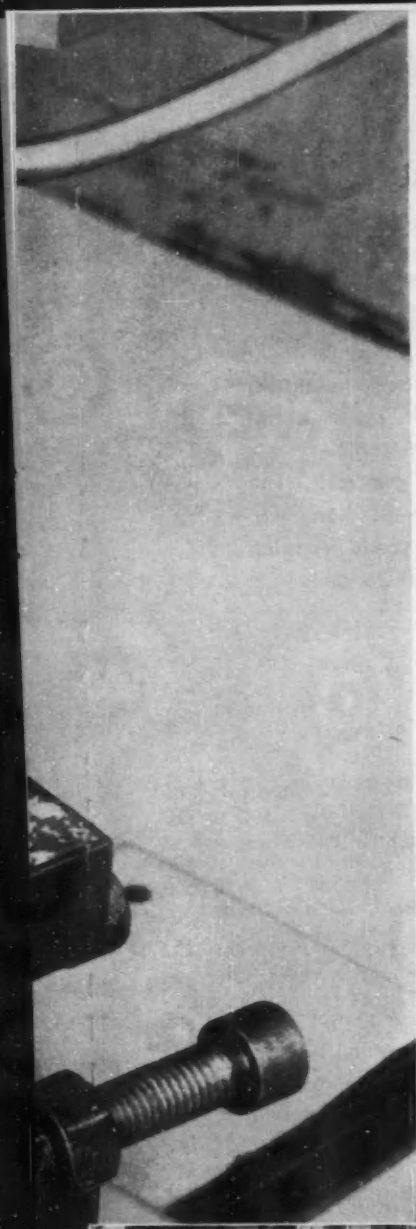
As the number of lanes increases to meet rising traffic demands, the cost of the centralized printing-counter equipment has risen proportionally, as has the cost of handling the data derived from the printed sheets. The information from the printed records includes number of vehicles of each classification passed by each collector, axle count for all lanes for each collector, total traffic in each classification for each lane for a particular hour, and total traffic in each classification for each lane for the day. The total quantity of data can be very large for a 50 lane system—14 x 50, or 700 registers. Subsequent sorting of the data is necessary to determine the classification count by collector and the hourly and daily totals. Since a collector may work three or four booths during a shift, the data handling is complex.

Magnetic drum system

With a magnetic drum system that has a low cost per register, the facility can set up the 700 registers needed for accumulating axle count and classification count per lane for the 50 lanes, and the same information for each of the 100 collectors who may be on duty that day. Registers can also be provided for the hourly and daily totals. The counts in these registers would accumulate as they are generated, eliminating the need for a subsequent data processing sorting operation and making the desired information available at any instant.

One track on the drum would carry information relating to one lane—14 registers for instantaneous count of axle and classification, 14 registers for the hourly totals, and 14 more for the daily accumulated total. Additional tracks would carry the accumulated classification counts by collector. If a read or write head fails, only data from one lane are lost.





New Univac Numerical Control System saves Rohr Aircraft up to 66% on machining costs

Less than four years ago, Rohr Aircraft had only one numerically controlled machine tool. Today, Rohr has nine—with numerical control data prepared by a UNIVAC® Solid-State Computer.

Rohr programmers simply describe in mathematical terms the shapes they want machined on a specific machine tool and the UNIVAC Solid-State automatically generates the control instructions that will guide the tool. *Result:* Thousands of metal parts of varied complexity turned out perfectly—and *economically*.

An aluminum upper engine mount, for instance, under conventional machine tooling, used to show a heavy scrap rate. Under numerical control with the UNIVAC Solid-State Computer, the scrap rate is now *zero*.

In one case, a three-dimensionally defined part was produced under numerical control at 1/40th the cost under conventional machining.

Rohr's over-all savings are as much as three to one, a saving of up to 66% on machining costs!

Here's what H. C. Emerson, Rohr Manufacturing Engineering Manager, has to say about the UNIVAC Solid-State Computer: "We chose the UNIVAC Solid-State because of its high storage capacity, fast processing speeds, low costs, availability and versatility. It not only handles our corporate data processing, but its application to numerical control has been extremely successful."

Yes, what's important to all industrial executives is that Univac offers a low-cost, medium scale, general purpose system that not only has proved itself in over 300 commercial installations but, at no additional cost, can handle with ease highly diversified numerical control part programs. Interested? Our local representative will gladly brief you on Univac Numerical Control—for your own installation or through your nearest Univac Service Center.

UNIVAC

DIVISION OF SPERRY RAND CORPORATION

UNIVAC Solid-State controls machining of three dimensional blowout door frame and engine mounting longerons.

Engine mounting box-beam for aircraft, milled from structural steel with help of UNIVAC Solid-State Computer.

Vacuum chuck being milled from aluminum plate with UNIVAC Solid-State produced data.

CIRCLE 81 ON READER SERVICE CARD

A Chemical Company's Survey Gives Edge to Electronic Instruments

In the 10 years since the introduction of electronic process controls, little has been done to test their characteristics against the older pneumatic controls. Du Pont recently installed an extensive electronic system and compared it with a pneumatic one controlling a similar process. The electronic instruments performed with less error, allowed installation with longer transmission distances, and required fewer and less costly repairs. Moreover, maintenance men preferred the electronics almost four to one.

M. M. DeLANCEY, Belle Works,
E. I. du Pont de Nemours & Co.

The major potential advantages of electronic process control instruments lie in better control because of lower hysteresis, no transmission lags, and lower maintenance costs resulting from cheaper replacement parts. To evaluate these advantages against those of pneumatic instruments, Du Pont used maintenance records on punched cards, obtained from mechanics working on both types of instruments. Both types were in service on the same process. In addition, maintenance men who worked on both systems answered a questionnaire covering their experiences and preferences.

The electronic control installation was completed in the spring of 1959. It was an extensive installation involving over 900 electronic units. Electronics had been chosen over the conventional pneumatic instruments for three reasons: 1) the process required a large number of measurements and controls, which had to be coordinated in a single control room; 2) the process equipment was spread over a wide area, with transmission distances ranging from 50 to 2,000 ft and averaging 700 ft; and 3) estimates of purchase and installation costs for both electronic and pneumatic units indicated that a large saving could be made by installing electronics. (This result cannot be applied to all projects since installed cost depends on purchase price, electrical classification, wiring methods, labor rates, and other factors.)

Instruments in the survey were confined to those with exact equivalents in both the electronic and pneumatic systems. These are listed in Table I. Because some instruments were common to both systems (pneumatically operated control valves, for instance), they were also excluded. Both systems were in service on the same process, so factors like plugging, freezing, corrosion, and the like affected the two systems similarly. The instruments of both systems were maintained by the same crew of mechanics under the same foremen, which was also an advantage for the comparison.

Comparing maintenance

Two objectives were involved in comparing the maintenance of the instrument systems. One was to study reliability and the other to compare maintenance cost. Table II shows the results of the repair data comparison. The total number of electronic instruments included in the comparison was

TABLE I — INSTRUMENTS STUDIED

ELECTRONIC	PNEUMATIC
Differential pressure transmitter	Differential pressure transmitter
Pressure transmitter	Pressure transmitter
Indicator and auto-manual station	Pressure controllers
Level transmitters (displacement type)	Level controllers and transmitters (displacement type)
Controller	Pneumatic controllers
T/C converter	Auto-manual stations
Resistance adapter	Pneumatic recorders (strip chart)
Elec./elec. converters (all types)	Temperature transmitters
Pneumatic/elec. transducers	
Recorder (strip chart)	

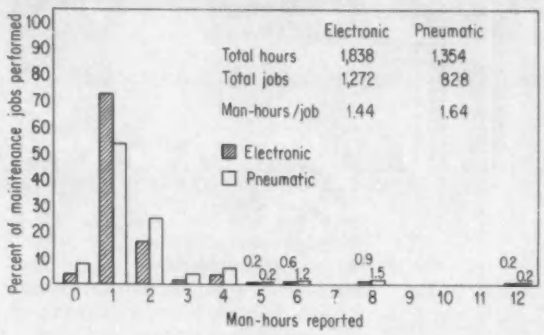


FIG. 1. Maintenance time breakdown shows time needed to repair each type of instrument.

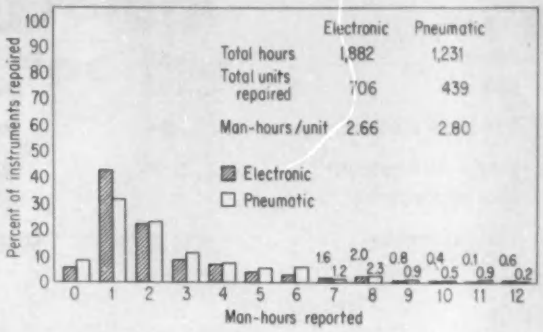


FIG. 2. Distribution of maintenance time shows time needed for individual instrument repair jobs.

904, and the corresponding number of pneumatics was 523. While this is a large difference in total numbers, Du Pont felt that the total of pneumatic instruments was sufficiently large that the results would be statistically significant.

Table II shows that the number of repair jobs required per instrument was 1.41 and 1.58 for the electronic and pneumatic systems, respectively. These repair frequency figures are a good measure of reliability and in this case slightly favor the electronics.

Average time spent repairing each type of instrument was 2.66 and 2.80 man-hours. Thus, the electronic instruments are slightly easier to repair. Figure 1 presents the data in another way. It shows the distribution of man-hours for each repair job. Here the difference between the instrument types is somewhat more striking, 1.44 man-hours versus 1.64. Also, Figure 1 shows that 72.4 percent of the repair jobs performed on electronic instruments were completed within 1 hour; only 53.8 percent of the pneumatic instrument repair jobs were done in this time. So the electronic instruments required repairs less frequently than did their pneumatic counterparts; and when it was necessary to repair the electronic units, it could be done faster.

Figure 2 presents the frequency of repair data of Table II to show that 42.8 percent of the instruments could be repaired in 1 hour, while only 31.9 percent of the pneumatic instruments could be repaired in that time.

Table III consolidates all of the labor and material costs on an annual repair bill basis. It shows that the yearly cost of materials for repairing the electronic system was very much lower than the cost of pneumatic instrument repair parts. The electronic parts are generally standard radio components

TABLE II — MAINTENANCE SUMMARY

	ELECTRONIC	PNEUMATIC
Total number of instruments	904	523
Total number requiring repair	706	439
Number not requiring repair	198	84
Total number of repair jobs	1,272	828
Total man-hours	1,882	1,231
Repair frequency — jobs/instrument	1.41	1.58
Repair time — man-hours/instrument	2.66	2.80

that are mass produced inexpensively, while the pneumatic instruments are usually made up of low-production mechanical subassemblies. Thus, while the cost of labor per instrument for the electronics was only slightly lower ($4.36 vs $4.91) than that for pneumatics, the cost of materials per instrument was so much lower for the electronics ($1.94 vs $4.89) that the total maintenance cost per instrument was 35.9 percent lower.

The accuracy edge

A comparison of accuracies was made using data submitted on the same punched cards used for the maintenance study. On these cards the mechanics reported the error they found on each calibration call as a percentage of full scale.

Figure 3 shows that 220 calibrations were made on the electronic instruments and 119 on the pneumatic. The average of all errors found was 2.3 and 3.3 percent, respectively. The data—broken down into groups—are plotted in the figure to show frequency distribution. It can be seen that 64.0 percent of the electronic instruments had "as found"

TABLE III — ANNUAL MAINTENANCE COST

	ELECTRONIC	PNEUMATIC
Material	$1,760	$2,560
Labor	3,940	2,570
Total number of instruments	904	523
Material cost/instrument	$1.94	$4.89
Labor cost/instrument	4.36	4.91
Total cost/instrument	$6.30	$9.80

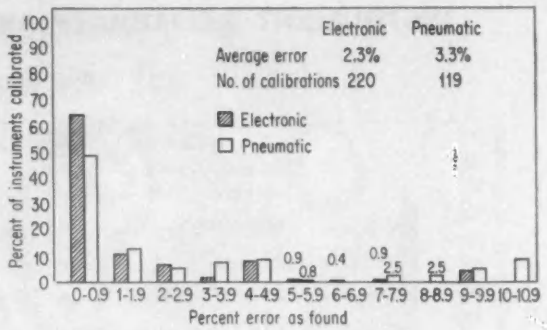


FIG. 3. Size of "as found" errors for the two types of instruments.

errors of below 1 percent; only 48.3 percent of the pneumatic types had errors in this range. A statistical analysis was carried out on the data, and it was found that the difference was probably real. The probability of its occurrence by chance alone was only 0.025. It might be concluded that these instruments are less susceptible to calibration drift. Here again a factor was found that favors the electronic instrumentation system.

Maintenance men's opinions

The opinions of the mechanics working on the two types of instruments were helpful in making the comparison because they brought out differences that did not show up in the numerical studies. A questionnaire was prepared which included questions designed to find the preference for each type of instrument. A group of 29 mechanics answered the questionnaire. All of these men had some experience working on the instruments included in the study. A majority of the workers had received formal training in the electronic gear, followed by practical experience in checking out the instruments during process startup. A few had had only casual training and experience. All of them were familiar with the pneumatic instruments.

A summary of the results of the survey is given, Table IV. Questions leading to the preference in transmitters and the controller covered relative ease of calibration or alignment, overhaul, and troubleshooting. The table shows that in only one case did the men favor pneumatics, i.e., temperature transmitters. Over-all, 60 percent of the crew favored electronics, 16 percent favored pneumatics—a ratio of almost four to one. The reasons most often given for this preference were: 1) easier to calibrate, 2) easier to repair because of plug-in construction, and 3) better control of process.

One user's opinions

Summing up the results of the system comparison, Du Pont drew the following conclusions:

- Generally speaking, the electronic instrument installation has been satisfactory.
- The electronic instruments do a satisfactory job of controlling the process.
- During the design stage there were no limitations on transmission distances.
- The electronic instruments have performed very well since startup, with few problems developing.
- The cost of maintaining the electronic instruments is somewhat less than that for the pneumatics.
- The electronic system is at least as reliable and, in fact, seems to require repairs less frequently.
- The electronic instruments seem to be more accurate.
- The electronic units seem to be easier to repair, and their circuit complexity is no real problem, as is evident from the mechanics' strong preference.

TABLE IV — SUMMARY OF OPINION POLL

	ELECTRONIC	PNEUMATIC	UNDECIDED
Easiest to calibrate	86%	0%	14%
Easiest to troubleshoot	52	17	31
Best control of process	48	10	42
Best diff. press. transmitter	73	13	14
Best pressure transmitter	74	11	15
Best temperature transmitter	31	36	33
Best controller	68	9	23
Best transmission	62	14	24
Holds calibration best	38	21	41
Easiest to learn	55	21	24
Average	60%	16%	24%

Graph Finds Temperature Sensing Bridge Response

ANDREW BARACZ, *Intercontinental Electronics Corp.*

Temperature sensitive bridges — with one, two, or all four arms variable —are frequently used in temperature control setups. The graph described here allows rapid evaluation of response for one and two variable arm types working into a matched load.

In a two variable arm bridge, Figure 1, the resistance change of the two arms is assumed equal and simultaneous. The magnitude of the change can be found from the physical characteristics of the materials used; these are chosen to suit the range being measured. The temperature sensing arms, diagonal to each other, have a high positive temperature coefficient; the remaining two arms have a very low or negligible temperature coefficient.

Applying Thevenin's theorem,

$$V_{AD} = \frac{V}{R + R_x} R \tag{1}$$

$$V_{BD} = \frac{V}{R + R_x} R_x \tag{2}$$

$$V_T = V_{AD} - V_{BD} = V \frac{R - R_x}{R + R_x} \tag{3}$$

$$I_L = \frac{V_T}{R_T} \tag{4}$$

$$R_T = 2 \frac{R R_x}{R + R_x} + R_L \tag{5}$$

For R_L to be matched to the internal resistance of the bridge R_T'

$$R_L = 2 \frac{R R_x}{R + R_x}$$

Therefore,

$$R_T = 4 \frac{R R_x}{R + R_x} \tag{6}$$

$$\frac{R_x}{R} = n \tag{7}$$

$$R_T = 4 \frac{n}{n + 1} R \tag{8}$$

Substituting Equations 3 and 8 into Equation 4 gives

$$I_L = \frac{V}{R} \frac{1 - n}{4n} = kI \tag{9}$$

$$k = \frac{1 - n}{4n} = f(n) \tag{10}$$

Thus $k = f(n)$ can be plotted, Figure 2, to give the response of the bridge. In this analysis the source resistance was assumed to be zero; this is usually near the actual case since the bridge is fed from a constant voltage source like a zener diode.

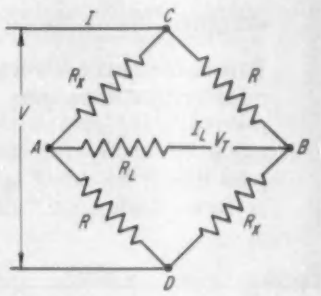


FIG. 1. A two variable arm temperature sensing bridge.

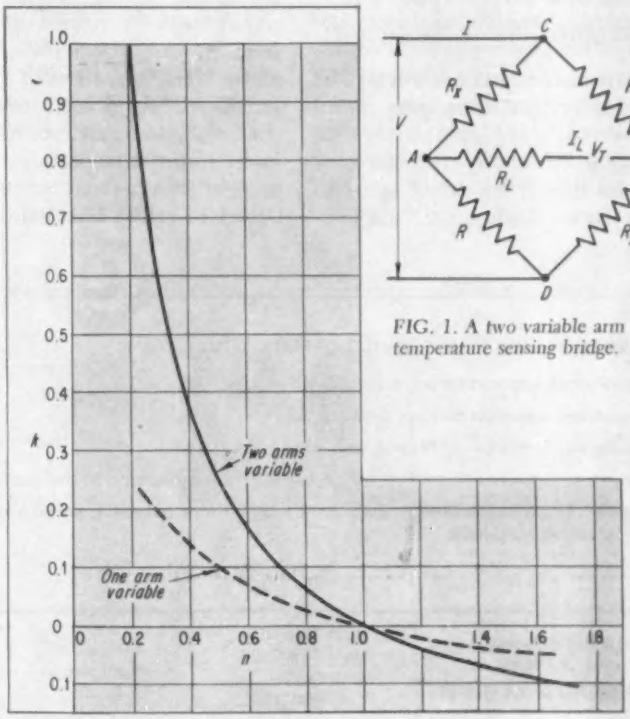


FIG. 2. Response of the bridge of Figure 1 is shown as solid line. Dashed curve indicates response when only one resistive arm is variable.

As an example, consider a coppermanganin bridge measuring a temperature rise of 50 deg C from an ambient of 20 deg C. If the bridge is balanced at this temperature, all arms will be of equal resistance and the output will be zero. From the characteristics of copper, the 50-deg C rise will increase the copper arms' resistance by about 20 percent, or

$$\frac{R_x}{R} = 1.2$$

From the solid curve, the bridge output corresponding to $n = 1.2$ is $I_L = -0.042I$, where I is the current fed to the bridge externally at balance conditions. The negative sign indicates the conventional polarity of the output. When only one resistive arm is variable, the dashed curve—for which $k = (1 - n)/(6n + 2)$—is used.

The curves also show that the response of the bridge can be improved if decreased values of n are used. In this case there will be a considerable current initially. Decreasing the arms' resistance until $n = 0.6$ at 20 deg C (for the two variable arm bridge) will give $n = 0.72$ at 50-deg C rise. The corresponding output currents will be $0.166I$ and $0.1I$, and the differential change will be $(0.166 - 0.1)\ I = 0.066I$. When the bridge feeds magnetic amplifiers, the standing current can be either balanced out magnetically or used as a biasing means.

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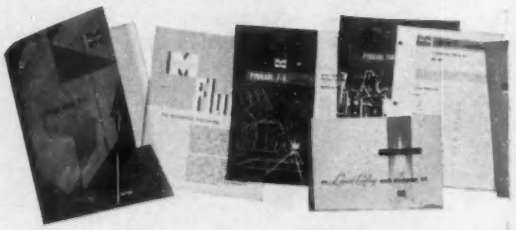

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COOLANOL 45	<−85 to >400	2400 @ −65 12.2 @ 100 3.95 @ 210	<−85	400	370
OS-59	−65 to 600	1380 @ −65 6.8 @ 100 2.2 @ 210	<−85	500	370
OS-124*	+40 to 900	363 @ 100 13.1 @ 210	+40	800	550
AROCLOR® 1242	+40 to 600	17.2 @ 100 2.5 @ 210	+2	600	fire resistant...
OS-80	(Preservative Fluid—*non-operational*				
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	430	**0.00048**	**0.89**	**0.45**	**0.080**
	435	**0.00046**	**0.88**	**0.45**	**0.077**
	660	**0.00033**	**1.204**	**0.365**	**0.075**
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***product*—protects systems in storage)**					
	340	**0.00045**	**1.00**	**0.40**	**0.070**

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CIRCLE 87 ON READER SERVICE CARD

Latest Japanese Numerical Control Features

- linear and circular interpolation for continuous path applications
- new staircase incremental interpolating technique
- direct-connected numerical director
- open-loop actuation using special electrohydraulic pulse motor

TOSHIMASA KAIWA & SEIUEMON INABA
Fuji Communication Apparatus Mfg. Co., Ltd.

The latest Japanese continuous path numerical control system parallels the approach of the domestic Bendix Dynapath system and GE's Mark Century insofar as all three are basically incremental systems and provide both linear and circular interpolation capabilities in a direct-connected numerical director. But the similarity ceases at this point, since the Fuji system uses a unique interpolating technique that approximates circles and straight lines by means of a staircase function, and employs open-loop controls on the machine without the conventional position measuring transducer and feedback link. The open-loop actuator is an electrohydraulic pulse motor, with electrical pulses driving an electrical stepping motor which positions a rotary servovalve. The valve in turn drives a rotary hydraulic actuator so that electrical pulses are transformed in one package into position and velocity controlled rotary hydraulic power.

Input to the system, Figure 1, is via six-hole perforated tape read by a 200 step per sec photoelectric tape reader. The reader is of the stop-on-character type so that the tape stops completely while the stop signal is still within reading range: start response time is about 0.004 sec. Input data are recorded in binary coded decimal. The synchronous serial computer-director uses straight binary for internal coding with nickel delay lines for memory elements. The circuitry is transistorized, as is all of the system's electronics. Interpolation is by the step approximation of arcs and straight lines but can be accomplished in only any two out of the three axes at one time (true three-dimensional contouring still requires the assistance of general purpose computer programming prior to the director). There are seven output channels from the director (positive and negative for each of the three axes and a control channel) connected directly to the machine control unit in the common console. Maximum output pulse frequency is 800 pps. With a typical unit step per pulse at the tool of 0.01 mm this gives a maximum cutting speed of 8 mm/sec (19 in./min).

The machine control portion accepts incremental pulse data from the numerical director and delivers three phase square waves to each of the electrohydraulic pulse motors on the machine feed screws. Right or left hand parts or symmetrical parts about the x axis can be obtained by flipping a switch. The bidirectional pulse motor responds well to frequencies up to 1,000 pps.

The manual control station is available in a floor-mounted console or in pendant form. The three dials provide for stepping of all three motors (depending on direction and distance of dial rotation) while the pushbuttons give continuous rapid traverse of any motor in either direction.

The system also has provision for cutter diameter indication. The punched tape is prepared for the profile of the finished workpiece (not for cutter-center path) and tool diameter is manually entered into the console. The director then automatically computes corrected beginning and end points for the various straight lines and arcs, thus generating the cutter-center path for the specified tool diameter. This feature will be described in another article.

Staircase Interpolation

The staircase method of interpolation approximates straight lines and arcs by a series of very small steps rather than by the end-connected straight lines or smooth curves developed by the usual linear and circular interpolating techniques. Interpolation from one block of instructions is possible in any one of the three planes xy, yz, and zx, and in any one quadrant of the selected plane. A new block of instructions is necessary when a continuous cut moves from one quadrant to another.

Consider the problem of linear interpolation in the first quadrant of the xy plane as shown in Fig-

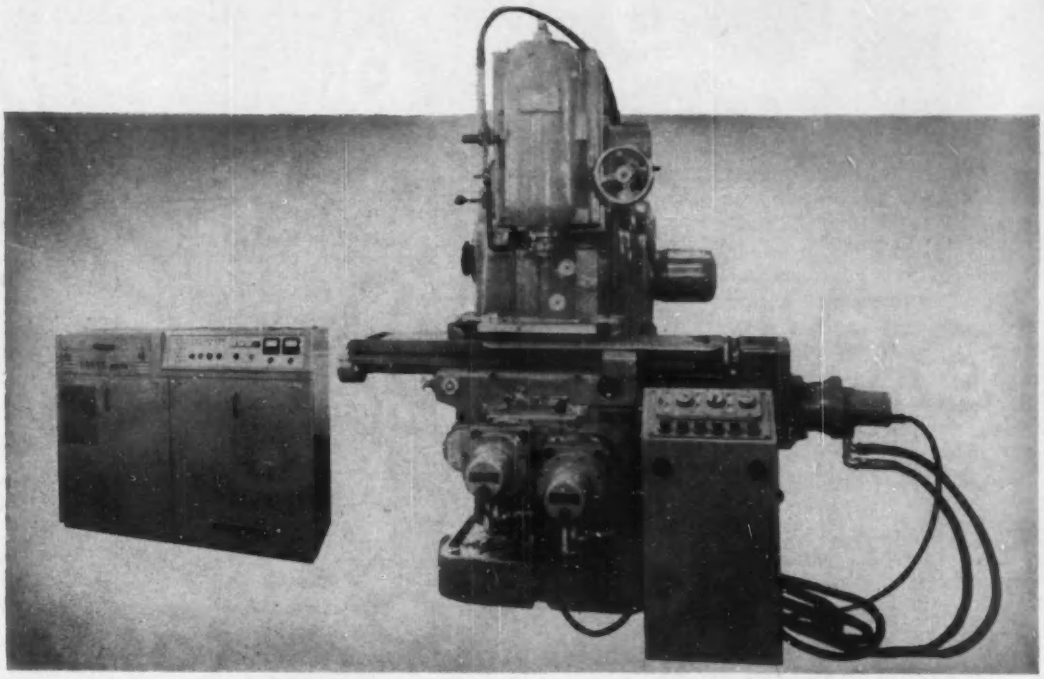


FIG. 1. System on vertical mill.

ure 2A. Assuming that the straight line starts at the origin of the coordinates, approximate the line with a series of steps until the end point P_e (x_e, y_e) is reached. Then any point (x, y) on the straight line satisfies the equation

$$x_e y - x y_e = 0 \tag{1}$$

And any arbitrary point on the plane but not on the line (x_i, y_i) falls above the line if

$$x_e y_i - x_i y_e > 0 \tag{2}$$

and below the line if

$$x_e y_i - x_i y_e < 0 \tag{3}$$

This forms the basis for the approximation procedure using very simple computing circuitry. In the first quadrant of the xy plane, if the tool lies on or above the line so that Equations 1 or 2 apply, one x pulse is delivered, while if the tool lies below the line so that Equation 3 applies, one y pulse is delivered. The tool starts at point P_0 and proceeds to points P_1, P_2, P_3, P_4, etc. to end point P_e. No point is more than one pulse from the true straight line. With a step at the tool of 0.01 mm the line is approximated within plus or minus 0.00039 in.

Arcs are handled in a similar manner as shown in Figure 2B, again for the first quadrant of the xy plane. With the origin of the coordinates taken as the center of the arc and the starting point of the arc being P_0 (x_0, y_0), then any point (x, y) on the arc satisfies the equation

$$(x^2 - x_0^2) + (y^2 - y_0^2) = 0 \tag{4}$$

If for any arbitrary point on the xy plane the left-hand term of Equation 4 is less than zero, then the point lies inside the arc and one pulse is applied to increase the y ordinate. In turn, if the left-hand

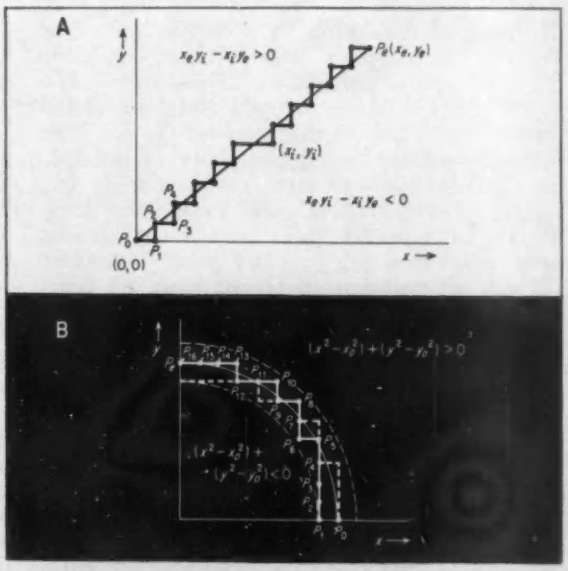


FIG. 2. Staircase interpolation applied to straight lines and arcs.

term of Equation 4 is equal to or greater than zero, the point lies on or outside the arc and one pulse is applied to decrease the x ordinate. This procedure yields a staircase approximation to the arc with all points lying within a tolerance band of plus or minus one unit step. This is for a counterclockwise cut; reversing the technique yields a clockwise cut. Both ccw and cw cuts are shown on Figure 2B.

In preparing a program for the numerical director

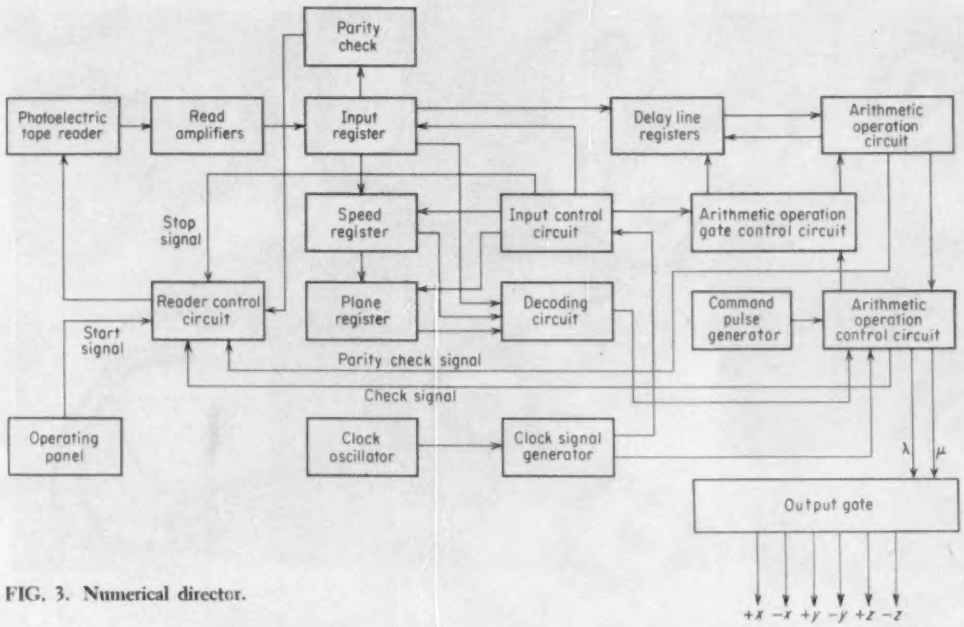


FIG. 3. Numerical director.

the origin of coordinates for a straight line cut is taken as the end point of the previous cut, while the origin of coordinates for a circular arc is taken as the center of the arc and the end point of the previous cut is the starting point of the arc. The following information must be recorded on the tape: for a straight cut—end point coordinates (x_e, y_e), cutting speed, coordinate plane, straight line designation, and quadrant; for a circular cut—starting point coordinates (x_0, y_0), end point coordinates (x_e, y_e), cutting speed, coordinate plane, arc designation, cw or ccw, and quadrant.

Numerical director operation

The director accepts this programmed punched tape, performs the necessary interpolation computations, and delivers incremental signals to the machine control unit. Figure 3 shows the block diagram of the director.

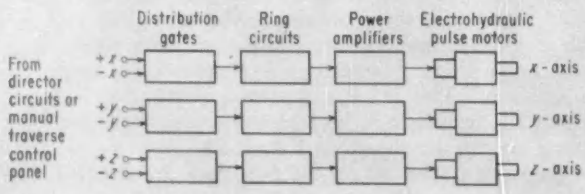
The information contained on the punched tape is read and stored in the input register after which the decoding circuit determines whether the information is a numerical dimension or whether it relates to speed or plane. If it relates to the latter, it is immediately shifted to the speed register by a parallel shift pulse from the input control circuit. If the information is numerical, a serial shift pulse from the input control circuit converts it to serial form while concurrently converting the binary coded number into binary form and delivering it to a nickel delay line memory.

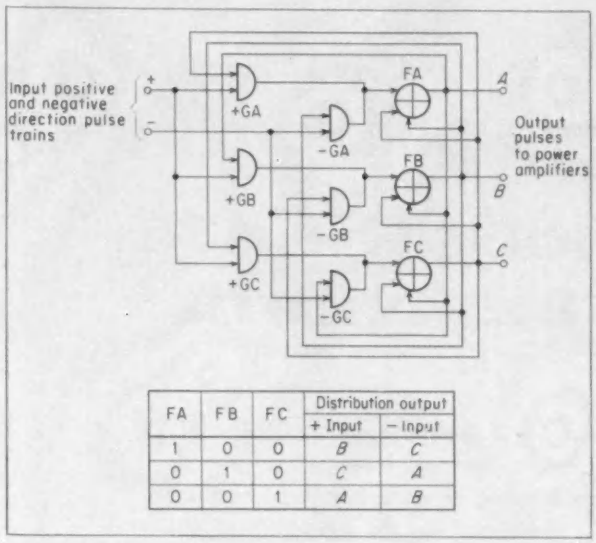
When all of the information has been read in and distributed, the arithmetic operation starts. The equations shown previously are solved on a point by point basis for arcs and straight lines, each calculation being checked to see whether the result is positive or negative. Depending on this discrimination, one pulse is sent to the λ or μ output line, while at the same time the contents of the corresponding register (x_0 or y_0) is increased or decreased by one pulse. In this way a gradual change takes place in the contents of the x and y registers until the end point values x_e and y_e are reached, completing the calculations for the instructions.

A crystal oscillator delivering 200 kc clock pulses provides the time standard for arithmetic operations. A word pulse, indicating the start of each cycle, is generated every 25 clock pulses.

The command pulses that are finally delivered to the machine control unit are derived from a command pulse generator. At the arrival of each command pulse, a clock pulse is sent to the λ or μ output line depending on whether the result of the preceding computation was positive or negative. The next computation then starts on the arrival of the next word pulse. Since every command pulse is delivered to the pulse motors, cutting speed depends on the

FIG. 4. Machine control unit.





FA	FB	FC	Distribution output	
			+ Input	− Input
1	0	0	*B*	*C*
0	1	0	*C*	*A*
0	0	1	*A*	*B*

FIG. 5.
Diagram shows distributor and ring circuits, table shows relationship between ring circuit condition and distribution of input pulse.

pulse frequency of the command pulse generator. This frequency is specified by tape recorded information and can be further modified over a ten to one range by the operator. Continuous operation is possible in the range of 50 to 800 cps.

The command pulse delivered over the λ or μ output line must be directed to the proper one of the six outputs shown in Figure 3, depending on the plane and quadrant. The output gate handles this switching and selection of pulse paths under the control of the decoding circuit.

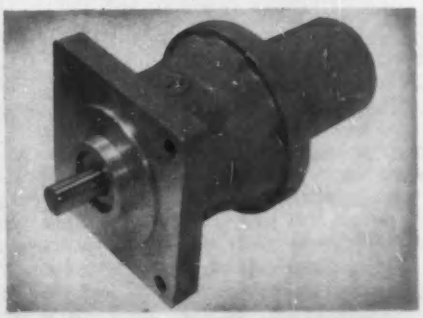
Machine control unit

The machine control unit accepts command pulses from the numerical director and distributes amplified signals to the three electrohydraulic pulse motors. Figure 4 shows the machine control unit in block form. Since the electrical stepping motors are three-phase devices, the incoming incremental pulse trains must be converted into three-phase signals of the proper sequence. This is accomplished in the distribution gates and ring circuits.

The distribution gate, Figure 5, distributes input pulses in the order *A*, *B*, *C*, or *A*, *C*, *B*, depending on whether the input pulses are arriving over the positive or negative input line. The ring circuit, also shown in Figure 5, consists of three flip-flops connected so that one of the three is always in the 1 state and the others are in the 0 state. When flip-flop *FA* is in the 1 state, gates $+GB$ and $-GC$ are enabled. Then when an input pulse arrives at the plus line it triggers *FB* through $+GB$, while an input pulse at the minus line triggers *FC* through $-GC$. With the input pulses distributed in this manner, the ring circuit rotates in the order *FA*, *FB*, *FC*, or *FA*, *FC*, *FB*. The table in Figure 5 shows the relationship between the condition of the ring circuit and the output distribution of the input pulse. The power amplifiers of Figure 4 amplify the outputs of *FA*, *FB*, and *FC* and deliver power pulses to the three-phase windings of the pulse motors.

Open-loop actuator

The open-loop electrohydraulic pulse motor actuator is shown in Figure 6. The electrical stepping motor drives a rotary four-way servovalve through a gear train. The output position of the axial-piston type rotary hydraulic actuator is fed back mechanically so the actuator output shaft continually follows the low power stepping motor. The output shaft exhibits a 3 deg step per input pulse and the unit will start instantaneously at pulse rates up to 500 pps with the maximum pulse rate being 1,000 pps. Output torque is 200 kg-cm at a pulse rate of 500 pps and a pressure of 70 kg/cm^2. Further details on the operation and performance of this unique actuator will be covered in a future article.



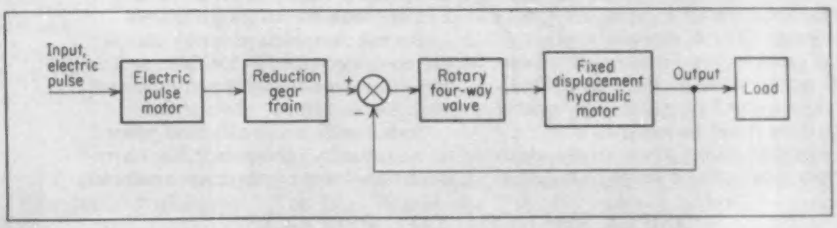


FIG. 6. Electro-hydraulic pulse motor.

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But that's not all. Every inch of Ampex Computer Tape is digitally checked to make sure every reel is completely error-free before it leaves the plant. What's more, it's tested on systems compatible with those it will be used on.

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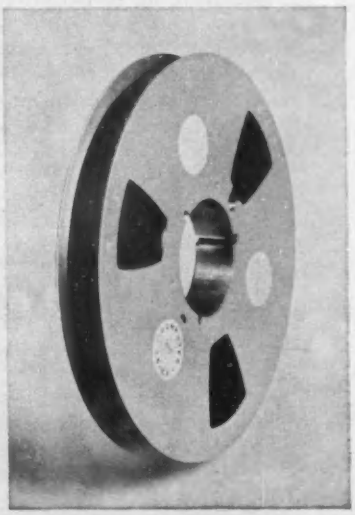

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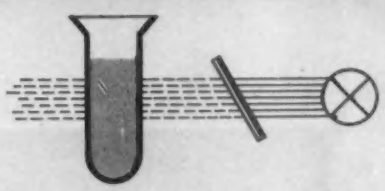


Predicting and Evaluating

The Performance of Analytical Instruments

THE GIST: When a chemical or physical property of a material is measured by an instrumental method, certain performance characteristics can be described and treated in a general way to determine quantitatively the overall performance of the instrument. The same basic principles are important to both the instrument designer and the application engineer.

This article defines the important performance factors of any measuring system and develops the general principles in a form that can be used to determine the performance of practical systems. The emphasis is on continuous recording radiation absorption analytical instruments for plant service.

V. N. SMITH,
Shell Development Co.

An ideal instrument would record or indicate a value directly related to the quantity to be measured and would be independent of all other factors. Such a relation may be expressed in the general form

$$R = f(q) \qquad (1)$$

where R is the recorder deflection in percent of full scale and q the value of the measured quantity. Also, the ideal instrument should respond instantaneously to a change in q. A further refinement would make the response linear in terms of the measured variable, so that

$$R = \frac{100}{q_{100} - q_o}(q - q_o) \qquad (2)$$

where q_{100} is the value of measured variable at full scale deflection and q_o the value of measured variable at zero point of recorder (zero suppression). The instrument *span* may be defined as

$$s = q_{100} - q_o \qquad (3)$$

Figure 1 shows the response of an ideal instrument. Such an instrument would have no errors and would always indicate the instantaneous true value. Unfortunately, the ideal instrument in this sense does not exist.

The real instrument and sources of errors

In practice any real instrument (or system) reading depends not only on the measured variable but also on many extraneous variables. Thus, for a real instrument, the recorder reading must be expressed more generally as

$$R = f(q, q_1, q_2 \ldots q_i \ldots) \pm \delta R \qquad (4)$$

where $q_1, q_2 \ldots q_i$ are such interfering quantities as ambient temperature, sample pressure, and amplifier gain, and δR represents random fluctuations introduced by detectors, amplifiers, vibration, etc. For example, an instrument may have an uncompensated sensitivity to temperature changes, Figure 2. The heavy line for temperature T_2 represents the response under the conditions prevailing at the time of calibration. The other lines in the family of response curves represent instrument response under other possible temperature conditions, ranging from T_1 to T_3.

These interfering variables introduce errors into the measurement. Some interfering variables or sources of error in a practical plant analyzer are listed in the table in three general categories: environmental, sample, and instrumental. An additional potential error source is in the initial instrument calibration carried out by the supplier—or by the user after plant installation.

Calculation of errors

An analyzer for plant service usually incorporates some internal environmental control and may be compensated for changes in the most serious interfering variables. However, the control and compensations are never perfect for all variables throughout their possible ranges. Therefore, the plant-type analyzer has an assumed calibration of the form of Equation 1. Actually, for a given recorder reading the true value of q would be given by

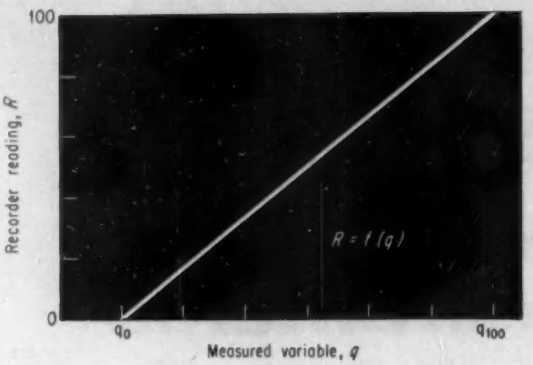


FIG. 1. Response of ideal stream analyzer.

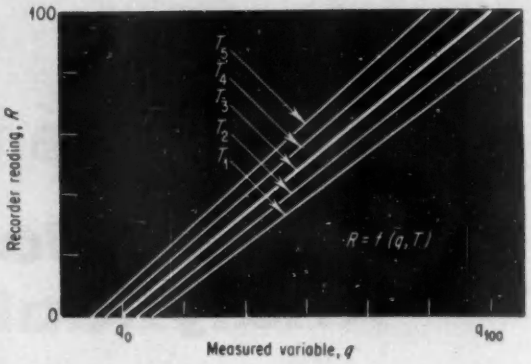


FIG. 2. Response of real stream analyzer having uncompensated temperature sensitivity.

a solution of Equation 4, provided the values of all variables and the true form of the equation were known. Because these factors are not usually known, the instrument readings are subject to errors depending on the deviations in the interfering variables, the instrument characteristics, and the initial calibration. Fixed errors due to incorrect calibration are not considered here.

In general, if there are simultaneous changes in the measured variable and other quantities (Δq, Δq_1, $\Delta q_2 \ldots \Delta q_i$), there will be a change in the recorder reading ΔR which can be approximated closely by the total differential of Equation 4:

$$\Delta R = \frac{\partial R}{\partial q}\,\Delta q + \sum_i \frac{\partial R}{\partial q_i}\,\Delta q_i \qquad (5)$$

If random noise δR is present the instantaneous deviation must include this term. Thus the actual recorder reading is

$$\Delta R = \frac{\partial R}{\partial q}\,\Delta q - \sum_i \frac{\partial R}{\partial q_i}\,\Delta q_i + \delta R \qquad (6)$$

Since the instrument is assumed to respond to changes in the measured variable only, the last two terms of Equation 6 represent an error E_m expressed in terms of the measured quantity as

$$E_m = (\Delta q)_{\text{apparent}} - \Delta q \qquad (7)$$

Then the error in the measured variable will be given by

$$E_m = \frac{\sum_i \frac{\partial R}{\partial q_i}\,\Delta q_i + \delta R}{\frac{\partial R}{\partial q}} \qquad (8)$$

Equation 8 can be used to calculate the maximum error from the known instrument characteristics and from maximum deviations in the interfering variables. If all variables change in a completely random fashion with standard deviations Δq_i, and the noise δR is the rms value, the standard deviation in the measured variable is

$$E_{ms} = \frac{1}{\frac{\partial R}{\partial q}}\left[\sum\left(\frac{\partial R}{\partial q_i}\,\Delta q_i\right)^2 + (\delta R)^2\right]^{1/2} \qquad (9)$$

However, the maximum error calculated from Equation 8 is often a more useful performance guide than the standard deviation, because most interfering variables, like ambient temperature, barometric pressure, and sample composition, vary slowly and introduce systematic errors, not random ones. More often, systematic errors are much larger than errors caused by random noise. If readings were averaged over a long time, compared with the deviation time of the interfering variables, E_{ms} would have some significance.

SOURCES OF ERROR IN PLANT ANALYZER APPLICATIONS

Environmental changes	Sample changes	Instrumental changes
Ambient temperature	Temperature	Noise
Barometric pressure	Pressure	Recorder calibration
Vibration	Flow	Amplifier gain
Radiation (e.g., sunshine)	Foreign matter	Power supply voltage
Humidity	Multiple phases (e.g., bubbles in liquid)	Column characteristics (in chromatographs)
Air pollution		Interference rejection or compensation
Line voltage	Physical properties (e.g., density, refractive index)	Mechanical stability
Cooling water temperature	Concentration of interfering components	Internal or local environmental control (temperatures, liquid levels, etc.)

Performance specifications

All common performance specifications for instruments can be defined in terms of the partial derivatives used in Equations 5 through 9. These performance figures may be defined as:

- Sensitivity: $S = \partial R/\partial q$
- Temperature coefficient: $S_t = \partial R/\partial T$
- Pressure sensitivity: $S_p = \partial R/\partial p$

▶Cross sensitivity: $S_i = \partial R/\partial q_i$

▶Discrimination ratio: $D_i = (\partial R/\partial q)/(\partial R/\partial q_i) = S/S_i$

The minimum detectable change in the measured variable is normally determined by the noise δR because the other variables change slowly and do not affect detection of a fast change in the measured variable. Then

▶Minimum detectable change: $(\Delta q)\text{min} = \delta R/(\partial R/\partial q) = \delta R/S$

Response time

So far, the measuring system has been assumed more or less instantaneous in response. In practice there will be a complex response time made up of sampling dead time and time lags plus various instrumental time constants. While this subject is beyond the scope of this article, it is important to consider response time because of the relation between speed of response and minimum detectable change in the measured variable. If the instrument itself is the source of all the noise and the instrument dynamic response alone can be characterized by a single time constant τ, then the noise on the recorder is

$$\delta R = NS/\tau^{1/2}$$

where N is a noise constant of the instrument.

Then, from the definition of minimum detectable change,

$$(\Delta q)\text{min} = N/\tau^{1/2} \qquad (10)$$

For a given instrument, where the noise N is fixed, the product of minimum detectable change and the square root of the time constant is a constant

$$(\Delta q)\text{min}\ \tau^{1/2} = N \qquad (11)$$

Thus, any desired increase in speed of response must be accompanied by a loss in ultimate sensitivity.

EXAMPLE OF ERROR CALCULATION—I

Measurement required:
Propylene (25-50 percent)
Ambient temperature range:
30-100 deg F
Interfering components in stream:
1) Ethane 5-15 percent
2) Ethylene 1-5 percent

An available instrument has these characteristics:
Zero point: 25 percent propylene
Full scale: 50 percent propylene
(Span = 50 −25 = 25 percent propylene, linear)
Temperature coefficient = 1 percent of full scale for 20 deg F
Discrimination ratios:
Ethane (q_1) $D_1 = 100$
Ethylene (q_2) $D_2 = 33.3$
Noise: δR = ±0.5 percent of full scale (max.)

Assuming the instrument is calibrated for the average values of the interfering variables, from Equation 8 the maximum error in the propylene measurement is

$$E_m = \frac{\dfrac{\partial R}{\partial T}\Delta T + \dfrac{\partial R}{\partial q_1}\Delta q_1 + \dfrac{\partial R}{\partial q_2}\Delta q_2 + \delta R}{\dfrac{\partial R}{\partial q}}$$

From temperature coefficient;

$$\partial R/\partial T = 1/20 = 0.05 \text{ per deg F}$$

from discrimination ratios;

$$1/D_1 = 0.01$$
$$1/D_2 = 0.03$$

and from span, $S = \partial R/\partial q = 100/25 = 4$ percent per 1 percent change in propylene.

The Δ's are taken from the stated conditions

$$\Delta T = \pm(100\text{-}30)/2 = \pm 35 \text{ deg F}$$
$$\Delta q_1 = \pm(15\text{-}5)/2 = \pm 5 \text{ percent ethane}$$
$$\Delta q_2 = \pm(5\text{-}1)/2 = \pm 2 \text{ percent ethylene}$$

Then the maximum error is

$$E_m = \pm\left(\frac{0.05\times 35}{4} + 0.01\times 5 + 0.03\times 2 + \frac{0.5}{4}\right)$$

$$E_m = \pm(0.438 + 0.05 + 0.06 + 0.125)$$
Temp C_2 C_2 Noise

$$= \pm 0.673 \text{ percent propylene}$$

Inspection shows that temperature error is most significant: if the temperature coefficient could be reduced by a factor of two, the maximum error would be reduced to ±0.454 percent.

It is important to realize that it is not always necessary to have a high discrimination ratio for a particular interfering variable because its error contribution also depends on the expected deviations in the interfering variable. Above, the errors introduced by ethane and ethylene are almost the same even though the discrimination ratio for ethane is 3 times that ethylene, because of the postulated deviations.

APPLICATION TO RADIATION ABSORPTION INSTRUMENTS

Many continuous plant stream analyzers, such as gamma ray densitometers, colorimeters, and infrared and ultraviolet analyzers, use the radiation absorption principle. Since such instruments have a common basis, it is worth while to study the general principles and apply the foregoing analysis in an evaluation of performance and limitations.

If a parallel beam of radiant energy of a given wavelength passes through homogeneous matter (solid, liquid, or gas), it is found that the fractional loss in intensity through a thin layer is proportional to layer thickness. This behavior has been observed experimentally and has also been justified theoretically for many different absorption mechanisms. With reference to Figure 3, this law can be expressed as

$$dI_x/I_x = -\mu dx \qquad (12)$$

where I_x is the intensity of radiation at a distance x from the surface of the sample, and μ the absorption coefficient. Integration and substitution of boundary conditions yields

$$I_L = I_o e^{-\mu L} \qquad (13)$$

where I_o is the intensity incident on sample, I_L the intensity of exit radiation from sample, and L the total path length through sample.

Equation 13 is Lambert's exponential absorption law, which may be expressed in terms of the common logarithm base (10) as

$$I_L = I_o 10^{-\epsilon L} \qquad (14)$$

where ϵ is the extinction coefficient. The constants ϵ and μ are related:

$$\epsilon \log_e 10 = \mu, \quad \text{or} \quad \epsilon = 0.434\,\mu$$

The ratio of exit intensity to incident intensity is transmissivity:

$$T = I_L/I_o \qquad (15)$$

and percent transmission is

$$t = 100\, I_L/I_o \qquad (16)$$

In spectroscopic work a common parameter is optical density

$$d = \log_{10}(1/T) \qquad (17)$$

From Equation 14, $d = \epsilon L$.

If the radiation-absorbing agent is a single component present in the sample at a concentration c, the absorption coefficient is

$$\mu = \alpha c \qquad (18)$$

where α is the absorption coefficient per unit of concentration. This relation between absorption coefficient

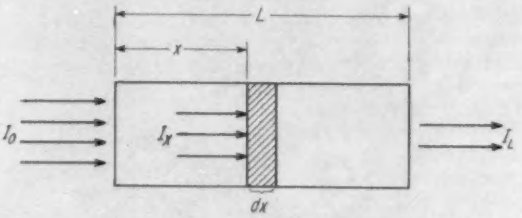


FIG. 3. Representation for deriving expression for energy absorption through sample cell.

and concentration is Beer's Law. When there are n absorbing components it is often possible to regard them as independent, so that the net absorption is the same for a mixture as it would be for n separate samples each containing the appropriate concentration of the component in question. Therefore, in generalized form Beer's Law is

$$\mu \sum_i \alpha_i c_i \qquad (19)$$

where α_i is the absorption coefficient per unit concentration of component i, and c_i the concentration of component i. Then the complete general form of the Beer-Lambert absorption law is

$$I_L = I_o \exp\left[-L \Sigma \alpha_i c_i\right] \qquad (20)$$

Equation 20 applies strictly to radiation of a single wavelength only (e.g., monochromatic light). In most analytical instruments a broad spectrum is used, and an exact analysis requires integration of Equation 20 over the effective energy spectrum. However, in many applications Equation 20 is valid to a first approximation.

SINGLE-BEAM INSTRUMENT

The simplest absorptiometric instrument is the single-beam arrangement, Figure 4. The response equation for such an instrument may be derived as follows: since only a fraction k_1 of the total source power (I_o) is incident on the sample cell window, then

$$I_o = k_1 I_o \qquad (21)$$

Now if the sample cell windows taken together transmit a fraction k_2 of the incident energy, and the sample transmissivity is T, the intensity of the radiation emerging from the cell will be

$$I_L = k_1 k_2 T I_o \qquad (22)$$

Usually the detector transforms the radiant energy into current or voltage signal. If the detector sensitivity is k_3, a signal

$$e_d = k_1 k_2 k_3 T I_o \qquad (23)$$

will be generated by the detector as a result of the radiation. In general there will be a noise signal $\pm N$ made up of detector noise and amplifier input noise, which must be added to the signal given by Equation 23. The amplifier input signal is then

$$e_i = k_1 k_2 k_3 T I_o \pm N \qquad (24)$$

Finally, if the amplifier gain is k_4 and the recorder sensitivity is k_5, the response equation will be

$$R = k_1 k_2 k_3 k_4 k_5 I_o T \pm k_4 k_5 N \qquad (25)$$

If α_m is the absorption coefficient and c_m the concentration of the component to be measured, the sample transmittivity is

$$T = \exp\left[-L\left(\alpha_m c_m + \sum_j \alpha_j c_j\right)\right] \qquad (26)$$

To calculate the performance parameter and error of the single-beam analyzer, the response equation is obtained by substitution of Equation 26 into 25,

$$R = K \exp\left[-L\left(\alpha_m c_m + \Sigma \alpha_j c_j\right)\right] \pm k_4 k_5 N \qquad (27)$$

where $K = k_1 k_2 k_3 k_4 k_5 I_o \qquad (28)$

may be thought of as an instrument sensitivity factor independent of the nature of the sample and the sample cell length.

In summary, the performance parameters and error for a single-beam instrument are

▶ Sensitivity—

$$S_m = \alpha_m LKT \qquad (29)$$

▶ Cross-sensitivities—For the interfering components in the sample,

$$S_j = \alpha_j LKT \qquad (30)$$

For the instrument parameters $K_1 \ldots K_5$ and I_o,

$$S_i = KT/k_i; \quad i = 1 \ldots 5 \qquad (31)$$

$$S_{I_o} = KT/I_o \qquad (32)$$

▶ Noise—

$$\delta R = k_4 k_5 N \qquad (33)$$

▶ Discrimination ratios—For the interfering components in the sample,

$$D_j = \alpha_m/\alpha_j \qquad (34)$$

Discrimination is determined completely by the absorption coefficients, which are constants of nature; no compensation for interference is provided by the instrument (single-beam).

▶ Instrument error—From Equation 8 the error equation for the single-beam analyzer is

$$E_m = \frac{1}{\alpha_m L}\left[L \sum_j \alpha_j \Delta c_j + \frac{\Delta I_o}{I_o} + \sum_j \frac{\Delta q_i}{q_i} + \frac{k_4 k_5 N}{KT}\right] \qquad (35)$$

This equation expresses the maximum error about an indicated value caused by maximum deviations (with the worst combination of signs) in parameters about their average values.

Consider the errors arising from the following individual sources:

1) deviations in interfering components—E_{m1}
2) deviations in instrument parameters—E_{m2}
3) noise—E_{m3}

Interfering components contribute an error

$$E_{m1} = \sum_j \frac{\Delta c_j}{D_j} \qquad (36)$$

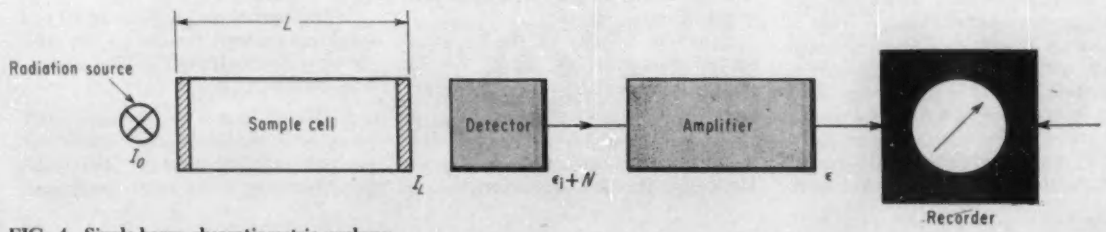


FIG. 4. Single-beam absorptiometric analyzer.

independent of instrument parameters.

Instrument parameters contribute an error

$$E_{m1} = (1/\alpha_m L)/(\Delta K/K) \quad (37)$$

Noise contributes an error

$$E_{m2} = (1/\alpha_m LT)/(N/e_1) \quad (38)$$

where $e_1 = k_1 k_2 k_3 I_s$ is the detector signal with the sample cell empty ($T = 1$).

With the single-beam instrument the errors caused by instrument parameter deviations can be serious because the errors are completely uncompensated. For satisfactory stability each parameter must be controlled within the limits set by ΔK in Equation 37. That is, the analyzer must maintain fixed mechanical positioning of components despite temperature or pressure changes ($\Delta k_1 \sim 0$); constant window transmission despite dirt in samples or environment ($\Delta k_2 \sim 0$); constant detector sensitivity despite temperature or humidity changes ($\Delta k_3 \sim 0$); constant amplifier gain in the face of aging tubes, temperature changes, etc. ($\Delta k_4 \sim 0$); constant recorder sensitivity ($\Delta k_5 \sim 0$); and constant source intensity despite changes in power supply or ambient temperature ($\Delta I_s \sim 0$).

Thus, the "simple" single-beam instrument actually requires very close control of all instrument parameters for satisfactory performance, a requirement that may be complicated and expensive to achieve.

Optimum cell depth for single beam analyzer

The criterion used here for determining optimum cell depth is minimum error. To determine optimum cell depth it is necessary to differentiate Equation 37 with respect to L, set the result equal to zero, and solve for the required cell length L. This procedure leads to the implicit function of cell length (L):

$$e^{\mu L}(\mu L - 1) = \frac{\frac{\Delta K}{K}}{\frac{N}{e_1}} \quad (39)$$

where $$\mu = \alpha_m c_m + \sum_j \alpha_j c_j \quad (40)$$

Although Equation 39 cannot be solved explicitly for L, it can be plotted, Figure 5, and μL (and thus L) can be determined graphically for any particular case where $\Delta K/K$ and N/e_1 are known.

It is worthwhile to reconsider the physical meanings of $\Delta K/K$ and N/e_1.

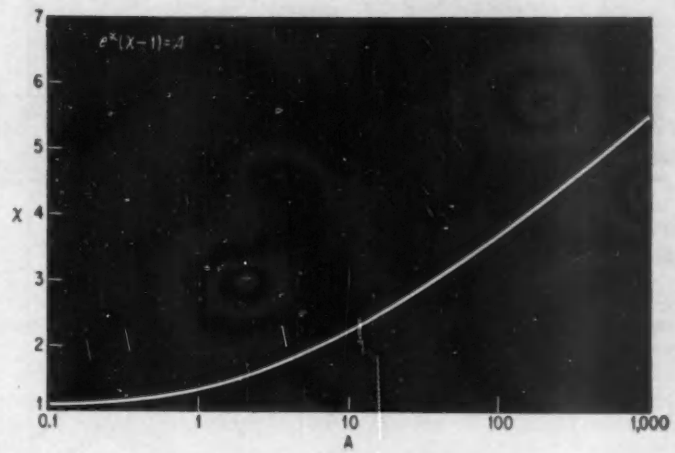


FIG. 5. Optimum cell depth function.

The quantity $\Delta K/K$ is the maximum fractional deviation in the lumped instrument sensitivity parameter. It is, of course, the sum of the individual maximum fractional deviations in source intensity, geometry, window transmission, etc., and may be expressed as

$$\frac{\Delta K}{K} = \frac{\Delta I_s}{I_s} + \frac{\Delta k_1}{k_1} + \frac{\Delta k_2}{k_2} + \frac{\Delta k_3}{k_3} + \frac{\Delta k_4}{k_4} + \frac{\Delta k_5}{k_5} \quad (41)$$

The quantity N/e_1 is the ratio of random noise (due to detector and amplifier input) to the signal level at the amplifier input when the sample cell is empty. Usually it is possible to measure or estimate both $\Delta K/K$ and N/e_1 reasonably well.

Three cases of particular interest are:

▶ If noise is the major problem,

$$N/e_1 \gg \Delta K/K;$$

then $e^{\mu L}(\mu L - 1) \to 0$

and $\mu L = 1$

In this case $T = 1/e$ or $t = 36.8$ percent, the familiar $1/e$ law for optimum cell depth.

▶ If instability of instrument parameters is the major problem,

say $\Delta K/K = 100\,(N/e_1)$

then $e^{\mu L}(\mu L - 1) = 100$

and $\mu L = 3.65$; $t = 2.6$ percent.

For no noise whatever, then $e^{\mu L} \times (\mu L - 1) \to \infty$, $L \to \infty$, and the maximum practicable cell depth would be used.

▶ If noise and instability are comparable.

say $\Delta K/K = N/e_1$; $e^{\mu L}(\mu L - 1) = 1$

and $\mu L = 1.28$; $t = 27.8$ percent

For the first case (where $\Delta K/K = 0$), it is interesting to plot the sensitivity function (Equation 29) as a function of L to see whether the choice of cell length is critical. Such a plot appears in Figure 6 (for the function $S_m = ALe^{-\mu L}$). The loss in sensitivity is only about 27 percent for a cell 0.4 or 2.0 of optimum length.

Single-beam instrument with zero suppression

The single-beam instrument has an inherent response to an infinite range of the measured variable because of the exponential character of the absorption law. However, in applying a plant stream analyzer it is often desirable to record the measured variable over some finite range of values. The analyzer must have a suppressed zero and a finite span. One simple method of accomplishing this is to use a recorder with a suppressed zero. The response equation will then have the form

$$R = k_5\left[\left(\frac{K}{k_6}\,T \doteq k_4 N\right) - e_o\right] \quad (42)$$

where e_o is the input signal to recorder for zero reading (suppression signal).

Analysis of this response equation will show that the error contributed by deviations in the recorder sensitivity factor k_5 vanishes at the value of the measured variable corresponding to recorder zero. This result confirms a fairly obvious intuitive conclusion, but is important as a stepping stone to more complicated systems.

If zero suppression is applied at the amplifier input rather than at the recorder, it is found that errors contributed by both recorder-sensitivity

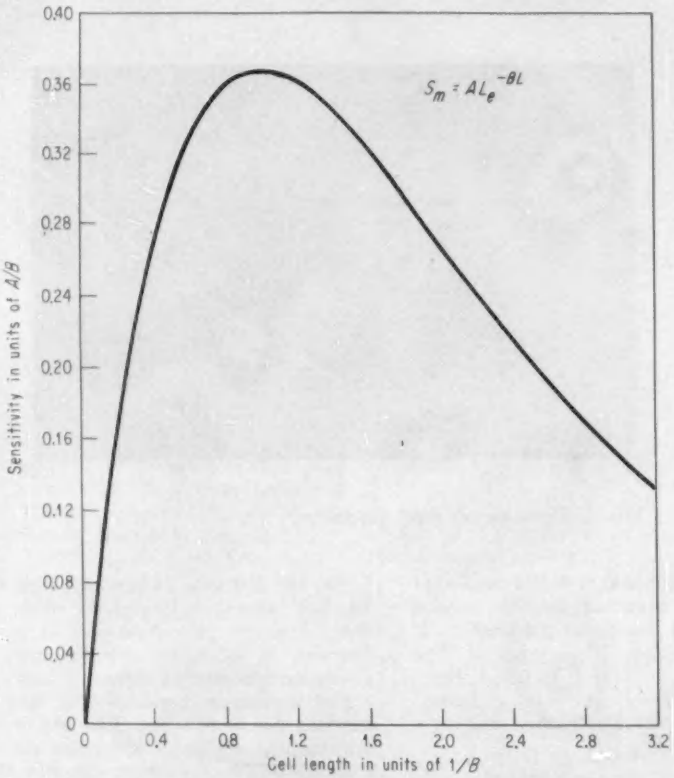


FIG. 6. Sensitivity as a function of cell length.

and amplifier-gain deviations vanish at the instrument zero point. This result illustrates the rule that zero suppression should be injected at the earliest possible point (closest to the radiation source) in the system. In fact, a complete duplicate of the analyzer, or better yet the multiplexing of identical components, to generate the zero suppression signal will minimize instrumental errors. The result is a double-beam analyzer.

DOUBLE-BEAM ANALYZER WITH DIFFERENCE MEASUREMENT

A general form of double-beam analyzer, Figure 7, contains separate radiation sources, separate optics, separate detectors, and separate amplifiers for generality. However, it is desirable to eliminate as many parallel elements as possible to improve stability. For example, if a common amplifier is used, changes in amplifier gain will cause no error at the null point.

Using primed symbols for the second beam, the following response equation for the double-beam instrument is valid:

$$R = K'T' - KT \pm [(k_4 k_5 N')^2 + (k_4 k_5 N)^2]^{1/2} \quad (43)$$

The sensitivity factor and transmission of the reference beam are set so that $R = 0$ when $T = T_s$, ignoring noise. That is,

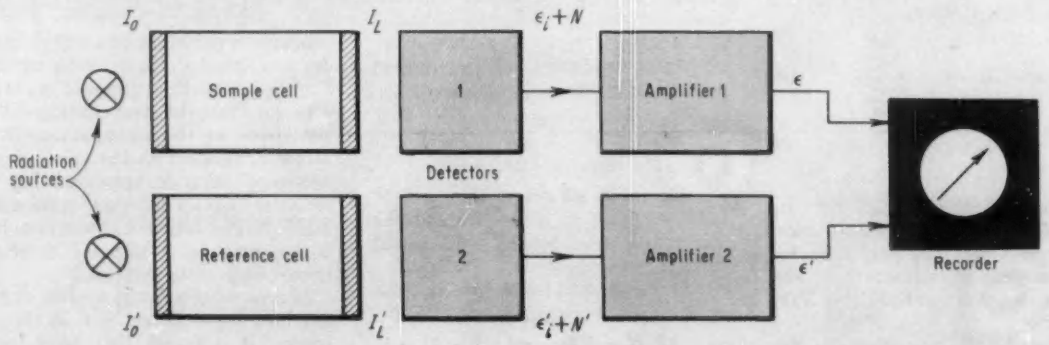
$$K'T' = KT_s \quad (44)$$

Here the recorder is simply reading the difference between the output signals of two single-beam analyzers, one of which serves as a reference and does not contain the sample stream to be analyzed.

The complex expression for the error in such an analyzer would show that there is no compensation for deviations in instrument parameters other than recorder sensitivity if these parameters vary independently. In practice, systematic changes in most parameters will have the same sign and be similar in magnitude in both beams. Hence a partial compensation exists at the zero point.

Further improvement can be realized by combining detector signals and using a common amplifier; then amplifier gain has no effect on readings at $T = T_s$. Similarly, by elimination of separate detectors and separate sources, the ultimate compensation possible in a double-beam difference-measuring instrument is reached. But this compensation is effective only at the zero point. Errors can be large on up-scale values because the recorder deflection is directly proportional to the factor K, so that changes in source intensity, detector sensitivity, etc., directly affect the reading. This difficulty may be over-

FIG. 7. Double-beam absorptiometric analyzer.



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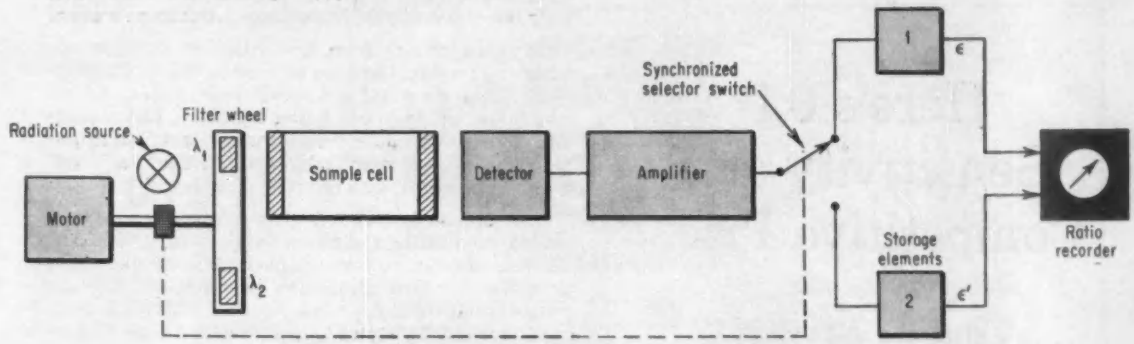

FIG. 8. Dual beam ratio recording instrument with single optical path and two wavelengths.

come by using a ratio recording system (or a null balance system).

DOUBLE-BEAM RATIO RECORDING INSTRUMENT

Many variations of the double-beam arrangement are possible (e.g. two sources, one detector; one source, two detectors, etc.). For simplicity in analyzing the double-beam ratio recording system, the arrangement will be considered with one source, one detector, and one amplifier. Figure 8 is one possible configuration. This system uses a ratio recorder (e.g. potentiometer recorder). Its response will have the form

$$R = k_s\,[(k_2'T')/(k_2T) \pm (N/e_1) - \rho_o] \quad (45)$$

where

$$\rho_o = (K_2'T')/(k_2T_o)$$

and k_s is the recorder sensitivity factor in terms of ratio and T_o the sample transmittivity at the value of the measured variable corresponding to zero on the recorder.

From the response equation the following error equation for the double-beam ratio recording instrument is derived:

$$E_m = \frac{1}{\alpha_m L}\left[L\sum_i \alpha_i \Delta c_i + \left(1 - \frac{T}{T_o}\right)\frac{\Delta k_s}{k_s} - \frac{T}{T_o}\frac{\Delta\rho_o}{\rho_o} + \frac{\Delta k'}{k'} + \frac{N}{e_1 T_o}\right] \quad (46)$$

where $k' = k_2'\,T'/k_2$

Deviations in the source intensity, detector sensitivity, and amplifier gain do not appear in Equation 46 and therefore are eliminated as sources of error. However, it is never possible in practice to make the radiation source or detector look perfectly identical in both beams regardless of the configuration used. For example, in an infrared instrument, if a single optical path and time sequenced filters are used to provide two wavelengths, Figure 8, the source intensity and the detector sensitivity and temperature coefficient will not be the same at both wavelengths. These factors may be taken into account in deriving the response equations by treating the source and detector as though they were dual instead of single elements. Then the instrument sensitivity parameter k' includes the ratios of source intensities and detector sensitivities as multipliers, but the general form of the equations for error and optimum cell depth is unchanged.

The expression for optimum cell depth for the double-beam instrument is much more complex than in the single-beam instrument. However, at recorder zero for minimum instrumental errors the expression has the same general form as for the single-beam instrument:

$$e^{\mu L}(\mu L - 1) = \frac{\dfrac{\Delta k'}{k'} - \dfrac{\Delta\rho_o}{\rho_o}}{\dfrac{N}{e_1}} \quad (49)$$

Thus Figure 5 may be used again in determining optimum cell depth. However, other limitations may prevent using the optimum cell depth. For example, the optimum length may be so long that the signal level is too small to operate the instrument using the available amplifier.

EXAMPLE OF ERROR CALCULATION—II

Determine ppm water in benzene:

$\alpha_w = 120\ \text{cm}^{-1}$ at 1.9 microns $\quad \alpha_\beta = 0.69\ \text{cm}^{-1}$

If the sources of error are

$$\frac{\Delta\rho_o}{\rho} = 0.001; \quad \frac{\Delta k'}{k'} = 0.001;$$

$$\text{and } \frac{N}{e_1} = 2 \times 10^{-4}$$

the optimum cell depth for the application will be given by

$e^x(x-1) = 100; \quad x = 0.69L = 3.65$

$L = 5.29$ cm

Then $T_o = e^{-4.65} = 2.60 \times 10^{-2}$

and the error at $T = T_o$ will be

$$E_m = \pm\frac{1}{120 \times 5.29}\left(0.001 + 0.001 + \frac{2 \times 10^{-4}}{2.60 \times 10^{-2}}\right)$$

$$= \pm 1.58\,(1 + 1 + 0.769) \times 10^{-4}$$

$$E_m = \pm 4.4 \text{ ppm}$$

The minimum detectable change is given by the noise factor alone,

$$(\Delta c_w)\text{min} = \pm 1.2 \text{ ppm}$$

and slower drifts (in window transmission, etc.) would introduce errors of ± 3.2 ppm.

It is interesting to compare this result with the error for a single-beam instrument having a similar noise level. The only difference is that $\Delta K/K = \pm 0.010$ is about the best practical stability. Hence, for optimum cell depth,

$e^x(x-1) = 500; \quad x = 0.69L = 4.86;$

$T_o = 7.7 \times 10^{-3}; \quad L = 7.05$ cm

and the error will be

$$E_m = \pm\frac{1}{120 \times 7.05}\left(0.010 + \frac{2.0 \times 10^{-4}}{0.77 \times 10^{-2}}\right)$$

$$= \pm 1.18\,(10 + 2.6) \times 10^{-4}$$

$$E_m = \pm 15 \text{ ppm}$$

and $(\Delta c_w)\text{min} = \pm 3$ ppm.

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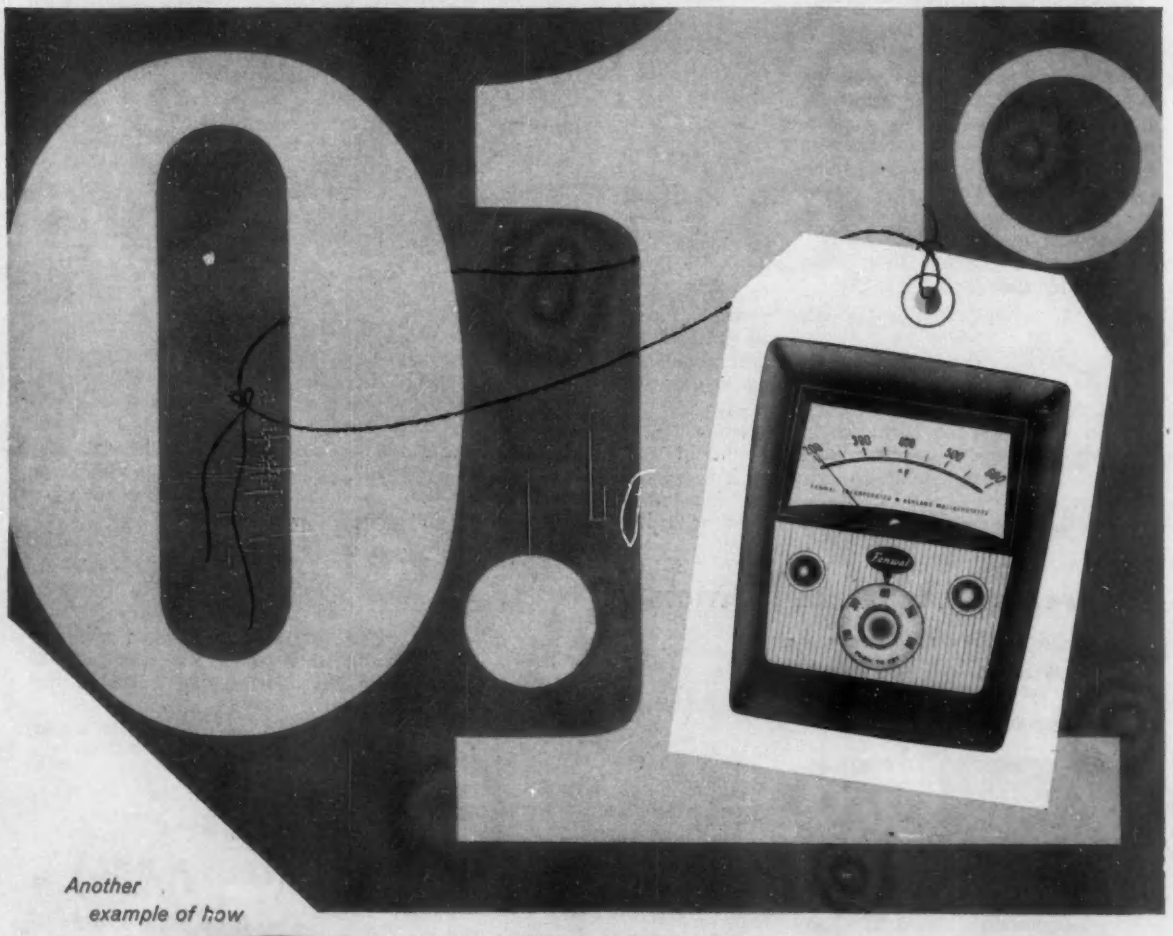

Another example of how

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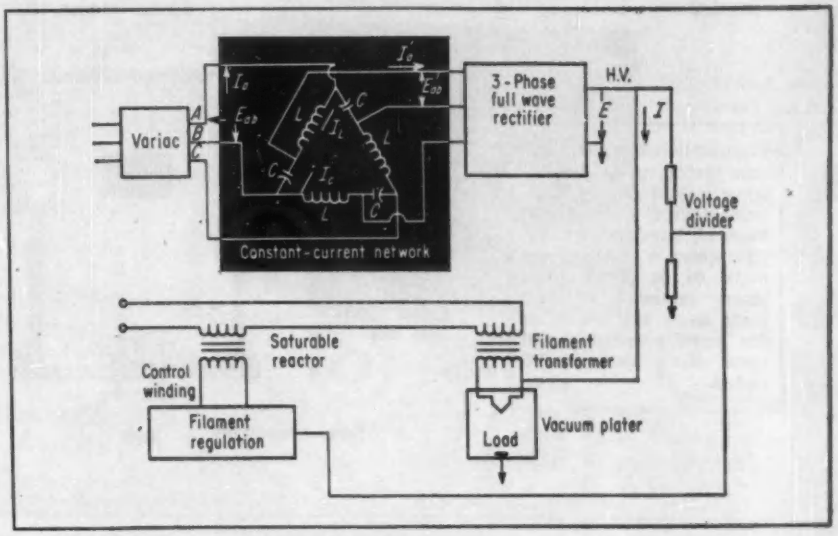


FIG. 1. Control system to supply constant current power. Network (reversed) converts constant voltage of variable autotransformer to constant current power supply of rectifier. This system limits power in electron bombardment vacuum plating process.

How to Supply Constant Current Power

ROYCE D. ECKARD and JOHN D. SALISBURY
Lawrence Radiation Laboratory, University of California

When electrical energy consumption has to be controlled carefully, as in an accurate electroplating operation, a constant current power supply is desirable. Here is the analysis of a network that can be used to convert a three-phase constant voltage power supply to a three-phase constant current input. In this article the network is applied to control vacuum plating by the electron bombardment process.

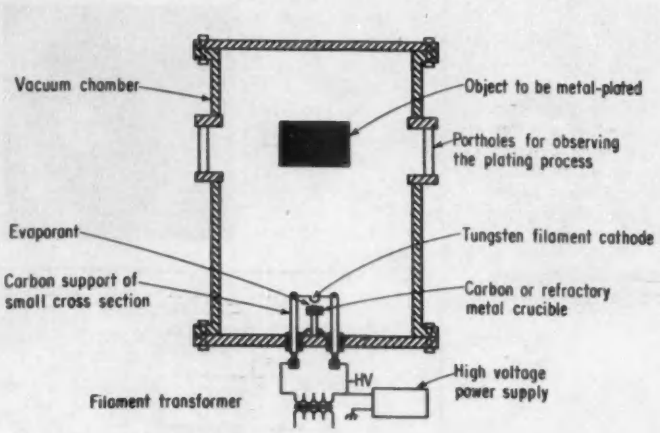
Electron bombardment vacuum plating (see box on next page) requires a current-limited power supply because glow gas discharges occur and these are essentially short circuits. In such an application a constant current power supply limits the power available to feed the discharge so the short is cleared rapidly. This feature supplies continuous operation, an essential for the process since any interruption in heating may ruin the plating run. A constant current supply can control other processes with similar restrictions.

The control system shown in Figure 1 contains a network that converts three-phase constant voltage power to a three-phase constant current input. The network regulates the power input to a standard, three-phase, full wave, 20-kw rectifier. With the network, the rectifier can supply any stabilized value of current or voltage from zero to the full rated direct current output of 4 amps at 5 kv.

Circuit analysis

If a single-phase constant current network were used, such as in Figure 2, an undesirable ripple factor would appear. A three-phase network reduces the ripple factor but the basic theory can be understood from an analysis of a single-phase network. The key point to prove is that the current through the resistance load Z is independent of the value of

Electron bombardment vacuum plating takes place in an enclosed envelope. Electrons emitted by the heated filament bombard the anode, which is made of the metal to be plated. The steady pounding of electrons heats the anode so the metal evaporates and coats the object to be plated.



the load's resistance. In Figure 2 (below), it is I_3. Here is the proof:

$$I_3 = \frac{E - I_1 Z_C}{Z} \tag{1}$$

Since $I_1 = E/Z_T$, then I_3 may be rewritten

$$I_3 = \frac{E - \dfrac{E Z_C}{Z_T}}{Z} = \frac{E}{Z_T}\,\frac{Z_T - Z_C}{Z} \tag{2}$$

The total impedance is

$$Z_T = Z_C + \frac{Z Z_L}{Z + Z_L} \tag{3}$$

so that $$Z_T - Z_C = \frac{Z Z_L}{Z + Z_L} \tag{4}$$

Substituting in the equation for I_3,

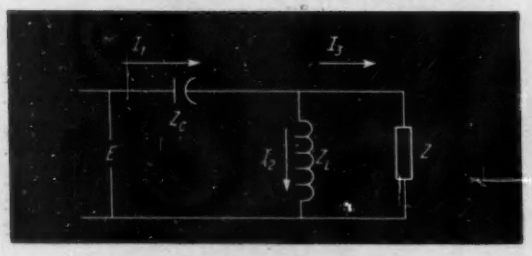
$$I_3 = \frac{E}{Z_T}\,\frac{\dfrac{Z Z_L}{Z + Z_L}}{Z} = \frac{E}{Z_T}\,\frac{Z_L}{Z + Z_L} \tag{5}$$

If the value of Z_T from Equation 3 is inserted in Equation 5,

$$I_3 = \frac{E}{Z_C + \dfrac{Z Z_L}{Z + Z_L}}\,\frac{Z_L}{Z + Z_L} = \frac{E Z_L}{Z_C Z + Z_C Z_L + Z Z_L}$$

$$= \frac{E Z_L}{Z_C Z_L + Z (Z_C + Z_L)}$$

FIG. 2. Single-phase constant current network illustrates the basic theory.



If the capacitor and inductor are assumed to be lossless elements, then, at resonance, when

$$Z_L = Z_C, \quad X_L = Z_L \quad \text{and} \quad X_C = Z_C$$

But X_C and X_L have opposite signs, so the term $(Z_C + Z_L)$ becomes zero and

$$I_3 = \frac{E}{Z_C} = \text{constant}$$

thus proving that I_3 is independent of the load.

In a practical circuit, the resistance of the capacitor can be neglected. As long as the parallel equivalent internal resistance of the inductor, whose value is approximately $Q\omega L$ (where Q is the sharpness of tuning and ω is the angular velocity), is large compared to the load impedance Z, its effect is small enough to be ignored.

This same reasoning can be applied to a three-phase circuit. The regulating network in Figure 1 is delta-connected and can be considered as three independent loads since the zero-sequence currents circulate in the delta. To simplify the analysis, the control engineer can consider the Y-equivalent of the delta load; Figure 3 (next page) shows one phase of the three-phase network in equivalent form. From this analysis, the currents and phase relationships can be determined.

The current in line 0′ should be maintained as a constant. By analysis by means of the superposition theorem (see Reference 1) the current is

$$I_a' = \frac{Z_2 E_{ca} + Z_1 E_{cb}}{Z_1 Z_2 + Z (Z_1 + Z_2)} \tag{6}$$

the current in the inductor is

$$I_{1a} = \frac{E_{ca} (Z + Z_2) - E_{cb} Z}{Z_1 Z_2 + Z (Z_1 + Z_2)} \tag{7}$$

the current in the capacitor is

$$I_{2b} = \frac{E_{ob}(Z_1 + Z) - E_{oa}Z}{Z_1 Z_2 + Z(Z_1 + Z_2)} \quad (8)$$

and the current in the constant power line is

$$I_a = \frac{E_{oa}(2Z + Z_1 + Z_2) - Z(E_{ob} + E_{oc})}{Z_1 Z_2 + Z(Z_1 + Z_2)} \quad (9)$$

These equations can be simplified by three assumptions:

1) $E_{oa} + E_{ob} + E_{oc} = 0$
2) There are negligible losses in the reactive components
3) The frequency is such that the reactances are of equal magnitude.

Since E_{oa}, E_{ob}, and E_{oc} are vectorially 120 deg apart,

$$E_{ab} = E_{ob} - E_{oa}$$

and because of the simplifying assumptions,

$$Z_1 = jX$$
$$Z_2 = -jX$$

Substituting these values into Equations 6 to 9,

$$I_a' = \frac{j E_{ab}}{X} \quad (10)$$

$$I_{2b} = \frac{Z E_{ab} + Z E_{ob}}{X^2} \quad (11)$$

$$I_a = \frac{3Z E_{oa}}{X^2} \quad (12)$$

Equation 12 is significant because it shows that the current in the constant potential supply line leads voltage E_{oa} if the load is inductive and lags E_{oa} if the load is capacitive. The constant current network reverses the apparent phase angle of the load.

The designer must calculate inductance L and capacitance C of the constant current network to make the actual network agree with this analysis.

Since the load—the rectifier—is a 20 kw device and the input power in the circuit of Figure 4 is 240 volt, three-phase, 60 cycle, the input power is

$$P_i = \sqrt{3}\, E_{ab}' I_a' \cos\theta$$

where $\cos\theta = 1$ because the rectifier load is practically pure resistance.

From this expression, the constant current I_a' is given by the equation

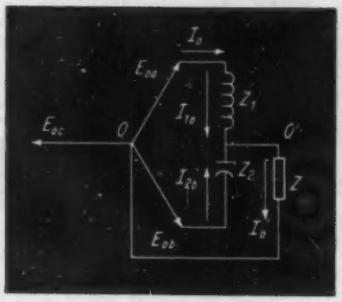


FIG. 3. Each arm of the network can be considered an independent load.

$$I_a' = \frac{P_i}{\sqrt{3}\, E_{ab}'} = \frac{20{,}000}{\sqrt{3} \times 240} = 48.1 \text{ amps}$$

It was already shown in Equation 10 that

$$I_a' = \frac{j E_{ab}}{X}$$

so that the reactance

$$X = \frac{E_{ab}}{I_a'} = \frac{240}{48.1} = 5 \text{ ohms} = |X_L| = |X_C|$$

From this reactance, it is easy to calculate the size of inductor and capacitor to use:

$$L = \frac{X_L}{j\omega} = \frac{5}{377} = 13.25 \text{ millihenries}$$

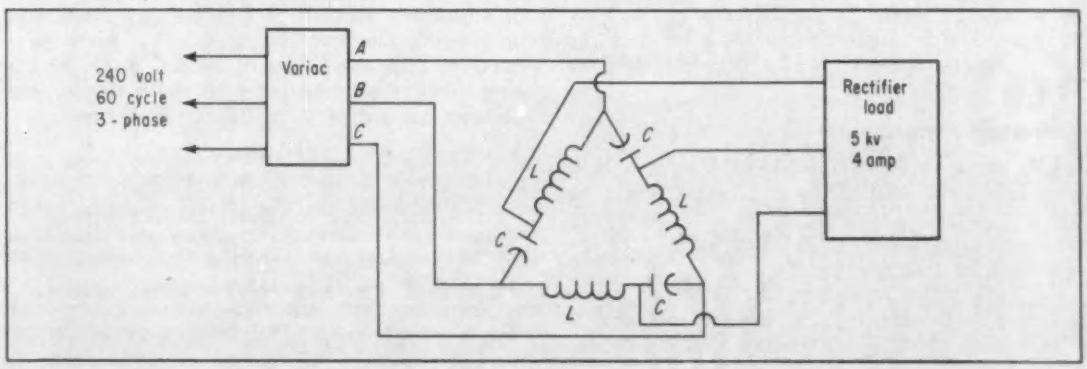
$$C = \frac{1}{j\omega X_C} = \frac{1}{377 \times 5} = 530 \text{ microfarads}$$

Changing the constant current value

In the physical circuit, Figure 5, capacitance Z_2 is composed of ten 50-microfarad capacitors in parallel; inductance Z_1 is an air core coil of 13.25 millihenries. The capacitors in parallel regulate the value of the constant current. When a capacitor is switched from impedance Z_2 to a parallel position with Z_1, resonance is maintained with an increase in reactance, and a corresponding reduction in current. Each capacitor switched reduces the output current by 10 percent.

Three switches have been used. One switches a

FIG. 4. Circuit parameters for the network.



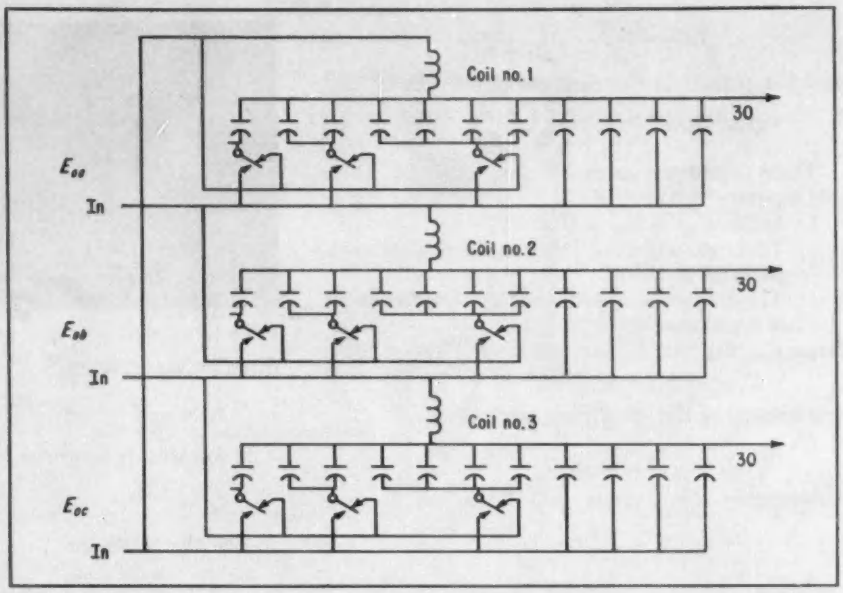


FIG. 5. Switching arrangement varies the value of the constant current output.

single capacitor from impedance Z_2 to Z_1, another switches two capacitors, and the third switches four. In this way, the current can be decreased in steps of 10 percent down to 30 percent of its maximum value. If currents are needed between these steps, line voltage E_{ab} can be varied to obtain them.

Load impedance control

The plating application dictates one other control requirement: load resistance must be held constant (except during flow discharges) to maintain the constant heating necessary for uniform plating. In this circuit, emission control of the filament stabilizes the load resistance, since the load is an emission-limited diode. The power dissipated is also controlled by filament power.

If the load voltage decreases, the filament regulator senses this change and decreases the current supplied to the control winding of the saturable reactor. Impedance of the reactor increases, thus decreasing the power to the filament of the load. In this way, a tendency toward any change of the load voltage is opposed by the filament regulator feedback loop.

Operating experience

Two larger three-phase networks have also been built, the largest rated 120 kw at 20 amps. These use iron core instead of air core reactors in the inductors. Iron core units are about one-half the size of the equivalent air core reactors.

For even better regulation, the value of $|X_L|$ in each arm of the network was selected so that it is a little larger than $|X_C|$ at normal load conditions. As the supply is loaded, $|X_L|$ decreases because the saturation curve is nonlinear; thus $|X_L|$ approaches the value of $|X_C|$. When $|X_L| = |X_C|$, maximum output occurs. This slight variation compensates for the resistance loss and the magnetization current loss of the plate transformer in the filament dc power supply.

Since the constant current power supply is in an overload condition when the output is open-circuited (as opposed to a constant potential supply which is overloaded when the output is shorted), a spark gap protects the power supply. It is placed across the input terminals of the plate transformer and adjusted to break down when the voltage reaches twice the normal value. An over-current relay is moved from a position in series with the output load current to in series with the spark gap so that any arc-over automatically shuts down the power supply.

The constant current power supply has other applications too. In one, it controls the temperature of a tungsten filament in a microscope illuminator light bulb. Filament temperature has been maintained at 2,400 deg K plus or minus 3 deg K for one hour. With a constant potential power supply, temperature has drifted 50 to 100 deg K per hour.

REFERENCES

1. *ELECTRONIC DESIGNERS HANDBOOK*, R. W. Landee, McGraw-Hill Book Co., New York, N. Y., 1957, Sec. 23, p. 32.
2. *THE MONOCYCLIC NETWORK FOR TRANSFORMING BETWEEN CONSTANT CURRENT AND CONSTANT POTENTIAL*, Steinmetz Alternating Current Circuit Calculations, General Electric Co.
3. *CONSTANT CURRENT POWER SUPPLY AND LOAD STABILIZER FOR ELECTRON-BOMBARDMENT PLATING PROCESS*, Royce D. Eckard, University of California Report UCRL-5914-T.

A NEW SERIES

Computer Equipment Comparisons

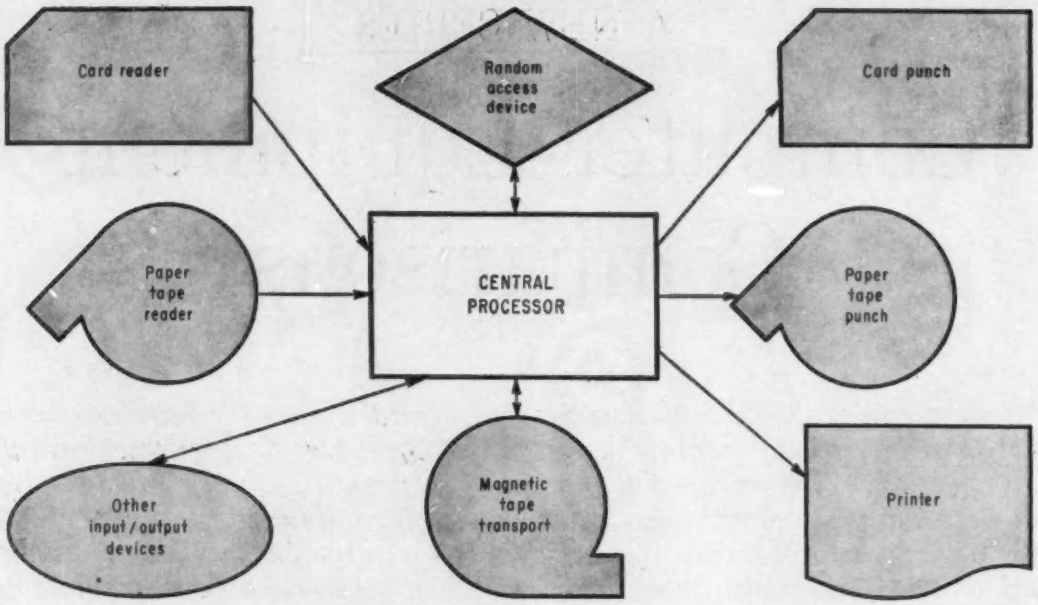
The most comprehensive comparison of digital computer hardware ever published begins this month in Control Engineering's Information Systems section. This series will compare in great depth the features and characteristics of electronic digital computers, analyzing the performance of central processors and input-output equipment including punched card devices, magnetic tape units, punched tape equipment, random access devices, and printers. These articles are being prepared exclusively for Control Engineering by the management consulting firm of Cresap, McCormick and Paget and will be designed for loose-leaf binding into a handbook of comparative data on appproximately 40 electronic computers. Complete and up-to-date collections of all articles on durable paper, and a special binder, will be made available through Control Engineering's reprint service as the series progresses. Subscribers may save the magazine pages if they prefer by taking advantage of the handy perforations used on all Control Engineering feature articles.

Prepared exclusively
for Control Engineering by
**CRESAP,
McCORMICK
and PAGET**

The objective of Control Engineering's Computer Equipment Comparison Series is to provide a really useful aid to management and systems engineers when deciding computer feasibility and selecting the equipment best suited to particular needs. In addition to comparative tabulations of all significant machine features, the articles will include glossaries of pertinent terminology for each type of equipment. The series will compare the newer general purpose, domestic solid state computers now being actively sold. For completeness, a few widely used vacuum tube computers will be compared too.

For the greatest usefulness of the comparisons, available computers can be divided into four size groups according to monthly rental costs for comparable installations—small, medium, intermediate, and large. Because rental costs can vary depending on the equipment included in a system, these groupings are neither clearly defined nor sharply divided and must be recognized as somewhat arbitrary. The monthly rental cost is a practical basis for grouping because justifying a computer usu-

A Basic Computer System



COMPUTERS TO BE COMPARED

Grouped by Monthly Rental Cost

MEDIUM
($5,000 to $14,000)

B200
(Burroughs Corp.)
B 205
CDC 160A
(Control Data Corp.)
GE 225
(General Electric Co.)
H 400
(Minneapolis-Honeywell Regulator Co.)
IBM 650
IBM 1401
NCR 304
(National Cash Register Co.)
NCR 315
Philco 2400
RCA 301
UFC
(Remington Rand Univac)
USS 80 or 90
(Remington Rand Univac)
USS II

INTERMEDIATE
($14,000 to $30,000)

G 20
(Bendix Corp.)
B 220
(Burroughs Corp.)
B 5000
H 800
IBM 1410
IBM 7070
RCA 501
U II
(Remington Rand Univac)
U III
U 490

LARGE
(Over $30,000)

CDC 1604
(Control Data Corp.)
IBM 704
IBM 705 III
IBM 7080
IBM 7090
Philco 2000
RCA 601
U 1107
(Remington Rand Univac)

ally requires comparing the monthly dollar expenditures under an existing system with monthly costs to operate a proposed computer system.

The table at left shows the computers that will be compared in the first series of articles. Small size computers will be compared later.

For the purposes of the series, computers will be considered as made up a central processor and several input and output devices as in the figure above. Each of the standard on-line input-output units will be compared in separate articles. The series will then compare the central processors (which include the computers' control, arithmetic, and memory units). Data processing equipment that can be operated in conjunction with an electronic computing system on an off-line auxiliary basis, such as punched card tabulators or sorters and certain medium converters and code translation devices, will be discussed in a separate group of articles after the computer equipment comparison series have been completed.

The series will compare computer equipment in the following order: punched card devices, paper tape devices, printers, magnetic tape devices, random access devices, and central processors. Other input-output devices available as optional equipment will be compared next, followed by system summaries for the medium, intermediate, and large size systems.

The Authors

M. STEPHEN FALK joined CMP in 1960 after four years of selling and installing data processing applications for The Service Bureau Corp. A graduate of Amherst, he has since spent most of his time in data processing studies for manufacturing and retail organizations, including the planning of client programming efforts. He is now concentrating on design of sales reporting, forecasting, operational systems, and inventory systems.

ROBERT G. SPENGLER did systems and equipment research on computers for Prudential Insurance Co. for seven years, then joined CMP in 1959. An electrical engineering graduate of Newark College of Engineering, he has participated in consulting assignments in systems and procedures for banks and trust companies, involving accounting and operational systems and equipment.

ALBERT KUSHNER is a partner in the management consulting firm of Cresap, McCormick and Paget. He has specialized in counseling on data processing problems since 1953. Formerly an Assistant Professor at Syracuse University, Mr. Kushner holds a Master's degree in mechanical engineering and a New York Professional Engineer's license. He is author of numerous articles and speeches on data processing for the NRMA, NMAA, AMA, NOMA, and other associations, and is directing the preparation of this series of articles.

JOHN J. CONNELL is a Boston College mathematics major who went on to Boston University's Graduate School of Business. At CMP since 1959, he has worked extensively in systems analysis, design of new systems, evaluation of EDP equipments, determination of EDP Staffing requirements, and scheduling of preinstallation and conversion procedures for banks, brokers, and manufacteurers. He came to CMP after seven years in EDP equipment sales with Burroughs Corp.

ROBERT C. SAVAGE held various sales and systems positions with IBM for four years before joining CMP in 1960 and has sold and installed punched card and computer equipment. Graduated from Lehigh University with Business Administration and Industrial Engineering degrees, he taught data processing at Fairleigh Dickinson University. At CMP, he has participated in EDP studies of computer feasibility, equipment selection, installation planning, and data processing organization for manufacturing and retailing concerns.

Punched Card Equipment for Medium Size Computers

This article discusses, defines, and tabulates for comparison the significant features and performance data on punched card input and output devices available as standard equipment with the popular medium size electronic computers. Next month's article will compare punched card equipment for larger computers.

Prepared by the staff of
CRESAP, McCORMICK and PAGET

Punched cards are widely used for getting information into and out of electronic computers. Originally developed and patented by Dr. Herman Hollerith in 1889, they have since been used in many different sizes with many different coding schemes. The two most popular types of cards in present use with electronic computers are the 80 column Hollerith (IBM) card and the 90 column Remington Rand card—both 7⅜ by 3¼ in. Information is recorded in the cards by holes punched by an operator using a card punch. The positions of the holes in each column represent a code for numeric, alphabetic, or other information. The IBM cards are punched with rectangular holes and the Remington Rand cards with round holes.

Data recorded on punched cards can be processed and organized in a number of ways on commonly available equipment before it is introduced into the computer. Available punched card machines can sort cards into any desired sequence, interfile them with other cards, add, subtract, multiply, or divide numeric data recorded on them, print out any part of this data, and manipulate the cards and the data in many other ways.

The most serious drawback in using punched cards as an input and output medium for computers has been the relatively slow speed of the card reading and punching equipment as compared to the internal speed of the computer itself. For example, one card reader can read at a rate of 800 cards per min. If all the cards to be read were punched in all 80 columns, the effective reading rate would be 64,000 characters per min. But the computer associated with this card reader can transfer 80-character records internally at a rate of 2,380,000 characters per min, which is approximately 37 times faster than the maximum character rate from the punched card reader.

Punched card input and output devices are sometimes housed in separate cabinets, Figures 1 and 2, and sometimes in the same cabinet, Figure 3. However housed, the reader is the input device, which reads data from punched cards placed in its feed hoppers, transmits this data to the computer, and places the cards that it has read in one or more stackers for removal by an operator. The output device is the card punch, which usually receives blank cards from its feed, punches data from the computer into the cards, and transfers the punched cards into one or more stackers. Some punched card devices can read and punch the same card.

Card readers and punches that serve respectively as input and output devices for computers are presented in separate Equipment Comparison tables. Tables 1 and 2 compare speeds, capacities, functions, possible data manipulations, and checking features in each of the available medium size computer punched card equipments. Comparisons are made only for features that are standard for the equipment or regularly offered as optional by the manufacturer. The tables do not compare custom built features.

The characteristics of card readers and punches do not of themselves indicate which computer is the best machine for a given application. Only an evaluation of total computer systems will reveal this. But comparison of punched card input and output equipment can reveal significant factors.

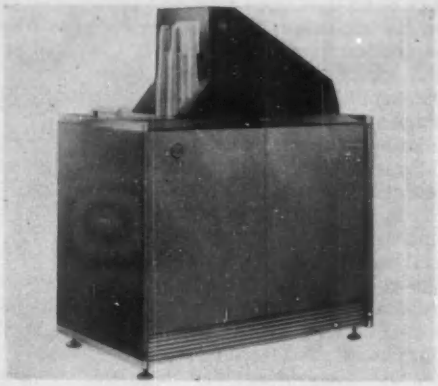


FIG. 1. RCA Model 323 card reader used with 301 computer is typical of readers housed in separate cabinet from card punch.

FIG. 2. Minneapolis-Honeywell H400 computer uses this Model 424-2 punch in separate housing from card readers.

FIG. 3. IBM 1401 computer uses this Model 1402 reader-punch with a radial stacker that permits removing cards without stopping operation.

CRITERIA FOR PUNCHED CARD EQUIPMENT

This section defines the criteria by which punched card input and output devices are compared in the Equipment Comparison tables.

The tables have two main divisions: *performance data*—which lists numeric quantities or speeds given by manufacturers' specifications, or calculated from specifications; and *capabilities*—which lists other characteristics of the equipment.

Performance data

The speed with which data can be read from or punched into the cards and the capacity of the card input and output devices are the primary performance criteria for comparing punched card input and output equipment.

• SPEED of card reading or punching depends on the rated speed of the reader or punch, and on the time-sharing ability of the computer.

Rated reading or punching speed is the maximum number of cards which theoretically can be read into or punched from the computer each minute.

Actual card reading or punching speed may be less than rated card reading or punching speed. The difference depends upon the time required by the computer to process data after they are read from or before they are punched into each card. For example, to maintain the rated punching speed the computer must be ready to transmit data at the precise moment that a card is ready to be punched. If the computer is not ready a percentage of the punching time is lost.

The number of holes to be read from or punched into a card has no bearing on the card reading or punching speed because the speeds of the input or output devices are geared to the handling of the cards rather than to the numbers of holes in the cards.

Time sharing ability indicates the maximum percentage of time available to the computer for the simultaneous performance of other operations while the card is being read or punched. The higher the percentage of time available the greater the amount of computing that can be performed during the card reading or punching time and the greater the possibility that actual reading or punching speed will equal rated reading or punching speed. In equipment for which the number of card columns affects time-sharing, the tables show minimum and maximum figures.

Certain computers have limitations which prevent some or all of their devices from sharing time with other devices.

• CAPACITY of card readers or punches is measured in various ways:

Maximum number of units indicates the maximum number of cards reading or punching units which can be connected into a computer system. Some computers can increase over-all card reading or punching speed by alternating the use of several

Table 1. PUNCHED CARD INPUT DEVICES (Medium Size Computers)

card readers or punches. This increase in speed is possible only if the system is not limited by the number or complexity of other operations which must occur between each card reading or punching.

Number of alphabetic columns read or punched is the number of columns of alphabetic data which can be read into or punched from the computer in a single card. While all computers can read or punch numeric data, some computers have limited alphabetic reading or punching capabilities.

Number of feeds is the number of hoppers into which punched cards can be placed for reading into the computer. The availability of extra feeds can often reduce the amount of card manipulation necessary prior to entry of cards into the computer.

This criterion does not apply to output devices because most card output devices punch into a supply of blank cards. Various card formats can be punched and the cards are sorted mechanically during or after the computer operation.

Feed capacity is the number of punched cards which can be placed in a feed hopper while awaiting reading into or punching from the computer.

Number of stackers is the number of output stackers which are available to receive punched cards after they have been read or punched. Just as with extra feeds, the availability of extra stackers can reduce the amount of card manipulation necessary to complete a processing operation.

Stacker capacity is the maximum number of punched cards which can be received in a stacker from the card reading or punching operation. Feed and stacker capacity are important because they give an indication of the frequency at which computer operations might have to be suspended in order to load or unload cards.

Capabilities

• FUNCTIONS of card readers and punches include read off-line, punch off-line, read only, punch only, and read/punch.

Read or punch off-line indicates a reader's or punch's ability to transfer data from punched cards to magnetic tape or from magnetic tape to punched cards without involving the central processor, which is thus free to do other operations.

Read only, or punch only, indicates that the computer is capable only of reading the data in the card being fed through the card reader or only of punching data into the card being fed through the card punch.

Read/punch indicates that the computer is capable of reading the data in the card being fed through it and is also capable of punching data into the same card. In devices of this type, the reading and punching stations must be synchronized; therefore, reading and punching occur at the same speed. The use of the read/punch capability thus reduces the over-all rated speed to that of the slower unit. However, by reducing the number of punched cards involved in a processing operation, this capability can sometimes reduce total job time.

• MANIPULATION of cards during card reading or punching includes sorting and format control.

Sort indicates the ability to separate the cards read or punched into more than one stacker, on the basis of a decision contained in the program stored in the computer. This ability can reduce later manipulation of cards which have been processed by the computer and depends upon the number of stackers on the reader or punch.

Format control indicates the availability of a plugboard or control panel on the punch card input or output device, which permits rearrangement and selection of data being read from or punched into cards, without computer intervention. The plugboards or control panels can be costly to buy, wire, and maintain. However, this cost can be offset by the reduction in computer time required to edit data after card reading or before card punching.

• CHECKING FEATURES ensure the accuracy of data being read from or punched into cards. These features may be divided into three groups: those used only in reading cards, those used only in punching cards, and those used in both.

Dual reading is used to check card reading. Each card column is read twice and the two readings are compared. Any comparison difference causes an error signal or stops the computer.

Read/compare is used to check card punching. Each card is read after it has been punched, and the data read are compared with the data at their source in the computer memory. Any comparison difference signals an error or stops the computer.

Validity checking is used to ascertain that no blanks or wrong combinations of punches are read.

Double punch/blank column detection may also be used to check card punching. The computer can automatically check specified columns of the card to ensure no blanks or invalid punch combinations.

Hole count is used to check both reading and punching. In card reading, the total number of holes punched in a card is counted at a first reading station and compared with the number of holes counted for the same card at a second reading station, thus checking the reading devices. In card punching, the total number of holes punched in a card are compared against a hole count generated by the computer, thus checking the punching device. In either case, differences in hole count will signal an error or stop the computer.

Misfeed or jam detection may also be used in checking both the card reading and punching devices. If any card fails to pass from the feed to a read station or to a punch station at the instant the device is ready to receive it, or if a card becomes jammed in the feeding mechanism of an input or output device, the device stops and in some cases signals an error.

NOTES FOR TABLES

a. Card readers, punches, or printers.
b. Any input-output device.
c. Average rather than maximum.
d. Requires a special feature which provides 80 columns on each of two readers and 30 on the third.
e. Separates only rejected cards into smaller stacker.
f. Printers or punches.
g. Varies with number of columns read.
h. Compares punch set-up with central processor.
j. Non-stop stacker: drawer, drum, or radial.
p. Punch side with special feature that permits reading.

Table 1 PUNCHED CARD INPUT DEVICES (Medium Size Computers)

COMPUTER	B 200		B 205		CDC 160 A		GE	225	H 400	IBM 650		
DEVICE MODEL NO.	B 124	B 122	IBM528	B 292	IBM088	IBM521	D 225B	D 225C	423-2	533	543	537
PERFORMANCE												
● SPEED												
Rated reading speed (cards per min)	800	200	200	300	1300	100	400	1000	650	200	250	155
Time-sharing ability (max percent)	96.0	99.0	0.0	85.0	99.9	99.9	99.0	97.5	43.0	79.7(c)	79.8(c)	76.8
● CAPACITY												
Max no. of units	2	2	1	7	2	2	1	1	1	3(a)	3(a)	3(a)
Number of alphabetic columns read	80	80	0	80	80	80	80	80 or 90	80	80(d)	80(d)	80(d)
Number of feeds	1	1	1	2	2	1	1	1	1	1	1	1
Feed capacity (cards)	2400	500	800	1000	3900	800	600	2000	3000	800	1200	800
Number of stackers	1	1	1	1	3	1	1	1	3	1	1	1
Stacker capacity (cards)	2400	500	800	1000	1000	800	600	2000	1000	800(j)	1900(j)	800(j)
CAPABILITIES												
● FUNCTIONS												
Read off-line	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Read only	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Read/punch	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	NO	YES
● MANIPULATION												
Sort	NO	NO	NO	NO	YES	NO	NO	NO	NO	NO	NO	NO
Format control	NO	NO	YES	YES	YES	YES	NO	NO	NO	YES	YES	YES
● CHECKING												
Dual reading	YES	YES	YES	YES	NO	NO	NO	NO	NO(h)	NO	NO	NO
Validity	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Hole count	YES	YES	NO	NO	NO	NO	NO	NO	YES	NO	NO	NO
Misfeed or jam detection	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES

COMPUTER	IBM 1401		NCR 304	NCR 315		Philco 2400	RCA 301	UFC		USS 80 or 90		USS II	
DEVICE MODEL NO.	1402	1402 (p)	380-3	380-3	383-1	...	323	80 col	90 col	Reader	Read-Punch	Reader	Read-Punch
PERFORMANCE													
● SPEED													
Rated reading speed (cards per mun)	800	250	2000	2000	400	2250	600	150	150	600	150	600	150
Time-sharing ability (max percent)	41.3	24.5	0	0	60 to 96(g)	100	20.0	99.9	99.9	97.5	99.2	97.5	99.2
● CAPACITY													
Max no. of units	1	1	1	1	1	64(b)	2	10(a)	10(a)	1	1	1	1
Number of alphabetic columns read	80	80	80 or 90	80	80	80	80	80	90	80 or 90	80 or 90	80 or 90	80 or 90
Number of feeds	1	1	1	1	1	1	1	1	2	1	1	1	1
Feed capacity (cards)	3000	1200	5000	5000	1000	4000	2000	600	600	1000	600	1000	600
Number of stackers	3	3	1	1	1	1	2	1	2	3	2	3	2
Stacker capacity (cards)	1000(j)	1000(j)	5000(j)	5000(j)	1000	4000(j)	2000 & 500(e)	1200	1200	1200	1200	1200	1200
CAPABILITIES													
● FUNCTIONS													
Read off-line	NO	NO	YES	NO	NO	NO	NO	YES	YES	NO	NO	NO	NO
Read only	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Read/punch	NO	YES	NO	NO	NO	NO	NO	YES	YES	NO	YES	NO	YES
● MANIPULATION													
Sort	YES	YES	NO	NO	NO	NO	YES(e)	YES	YES	YES	YES	YES	YES
Format control	NO	NO	NO	NO	NO	NO	NO	YES	YES	NO	NO	NO	NO
● CHECKING													
Dual reading	NO	NO	YES	YES	NO	YES	YES	YES	YES	YES	YES	YES	YES
Validity	NO	NO	YES	YES	NO	NO	YES	NO	NO	NO	NO	NO	NO
Hole count	YES	YES	NO	NO	NO	NO	YES	NO	NO	NO	NO	NO	NO
Misfeed or jam detection	YES	YES	YES	YES	NO	YES	NO	YES	YES	YES	YES	YES	YES

Table 2 PUNCHED CARD OUTPUT DEVICES (Medium Size Computers)

COMPUTER	B 200		B 205		CDC 160 A		GE	225	H 400		IBM 650		
DEVICE MODEL NO.	B 204	B 203	IBM528	B 292	IBM523	IBM521	E 225C	E 225D	424-1	424-2	533	544	537
PERFORMANCE													
● SPEED													
Rated punching speed (cards per min)	300	100	100	100	100	100	100	200	100	250	100	250	155
Time sharing ability (max percent)	99.0	99.0	0	95.0	99.9	99.9	97.1	94.2	16.7	26.3	90.2(c)	79.8(c)	84.5(c)
● CAPACITY													
Max no. of units	1	1	1	7	2	2	1	1	1	1	3(a)	3(a)	3(a)
Number of alphabetic columns punched	80	80	0	80	80	80	80	80	80	80	80(d)	80(d)	80(d)
Feed capacity (cards)	800	800	800	800	800	800	800	800	800	1000	800	1000	800
Number of stackers	1	1	1	1	1	1	1	1	1	1	1	1	1
Stacker capacity (cards)	800	800	800	800	800	800	800	800	1000	1200(j)	800	1200(j)	800
CAPABILITIES													
● FUNCTIONS													
Punch off-line	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Punch only	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Read/punch	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	NO	NO	YES
● MANIPULATION													
Sort	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Format control	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
● CHECKING													
Read compare	YES	YES	NO	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO
Double punch/blank column detection	YES	YES	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES
Hole count	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Misfeed or jam detection	YES	YES	YES	NO	YES	YES	NO	NO	NO	YES	YES	YES	YES

COMPUTER	IBM 1401	NCR 304		NCR 315		Philco 2400		RCA 301		UFC		USS 80 or 90	USS II
DEVICE MODEL NO.	1402	IBM523	IBM544	IBM523	IBM544	....	....	334	336	80 col	90 col	Read-Punch	Read-Punch
PERFORMANCE													
● SPEED													
Rated punching speed (cards per min)	250	100	250	100	250	100	250	200	100	150	150	150	150
Time sharing ability (max percent)	29.5	98.7	96.7	98.7	96.7	100	100	14.0	14.0	99.9	99.9	99.0	99.0
● CAPACITY													
Max no. of units	1	4(f)	4(f)	4(f)	4(f)	64(b)	64(b)	1	1	10(a)	10(a)	1	1
Number of alphabetic columns punched	80	80	80	80	80	80	80	80	80	80	90	80 or 90	80 or 90
Feed capacity (cards)	1200	800	1000	800	1000	650	650	800	800	600	600	600	600
Number of stackers	3	1	1	1	1	1	1	2	2	1	2	2	2
Stacker capacity (cards)	1000(j)	800	1200(j)	800	1200(j)	750	750	2000 & 100(e)	2000 & 100(e)	1200	1200	1200	1200
CAPABILITIES													
● FUNCTIONS													
Punch off-line	NO	YES	YES	NO	NO	NO	NO	NO	NO	YES	YES	NO	NO
Punch only	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Read/punch	YES	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
● MANIPULATION													
Sort	YES	NO	NO	NO	NO	NO	NO	YES(e)	YES(e)	YES	YES	YES	YES
Format control	NO	YES	YES	NO	NO	NO	NO	NO	NO	YES	YES	NO	NO
● CHECKING													
Read compare	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES
Double punch/blank column detection	NO	YES	YES	YES	YES	NO	NO	NO	NO	YES	YES	NO	NO
Hole count	YES	NO	NO	NO	NO	NO	NO	YES	YES	NO	NO	NO	NO
Misfeed or jam detection	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Get Maximum Reliability From Digital Magnetic Tape

THE GIST: The reliability of digital reproduction from magnetic tape generally cannot be improved simply by operating a recorder at lower bit packing densities. A recorder's maximum reliability or capacity for reliability does decrease as it is designed for higher and higher maximum packing densities. Thus, maximum reproducing reliability will be delivered in any particular application by a recorder that overdrives the write heads, and has just adequate frequency response and the widest practical head gaps for the highest bit rate required. In other words, the maximum design packing density of a recorder should be just high enough for the application.

KENNETH TAYLOR
Ampex Computer Products Co.

The reliability of reproduction from a digital magnetic tape recorder is commonly believed to be related to the so-called bit packing density of recording—that is, the greater the number of bits per inch recorded on the tape, the lower will be the reliability. But this is generally not true in practice. Loss of tape-to-head contact during writing or reading is the major cause of tape errors, and a digital recorder operating at a low packing density is just as sensitive to signal dropouts due to tape-head spacing as the same recorder at a higher packing density.

When a single bit is recorded as a pulse and reproduced, the output pulse from the read head has a specific frequency spectrum. In general, the loss due to spacing of the tape away from the head depends on the shortest recorded wavelength:

$$\text{spacing loss} = 55\, d/\lambda \text{ db}$$

where d is any tape to head spacing greater than the gap length and λ is the recorded wavelength, on the tape, of the highest significant frequency in the spectrum of the pulse. Therefore the loss due to head-to-tape spacing is independent of bit packing density for pulses that are completely independent of each other.

As pulses are packed closer and closer together a point is reached where they begin to modify each other. At very high recording densities, the signal loses all pulse characteristics and degenerates to a simple sine wave. The pulse crowding point is defined as the packing density at which the amplitude of the output is down 3 db from the amplitude of (isolated) pulses at very low packing densities, see Figure 1.

To the extent that reliability of reproduction can

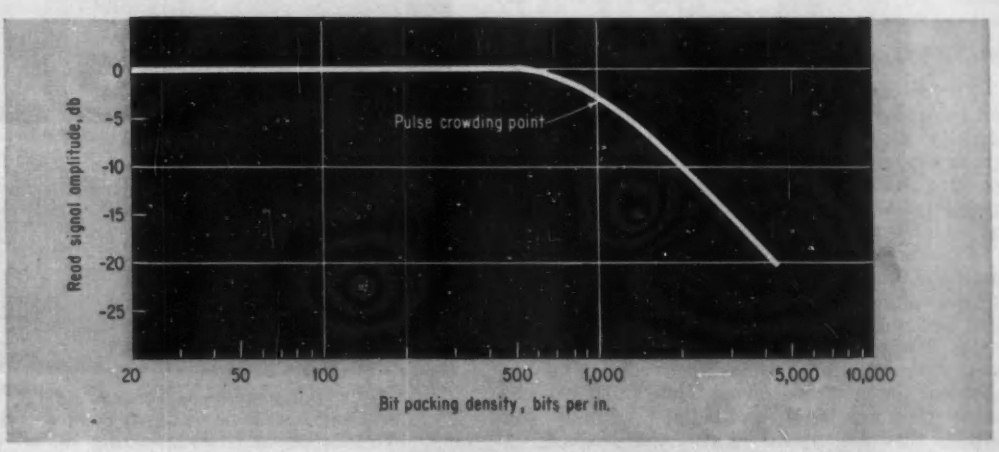


FIG. 1. Pulse amplitude in db as a function of bit packing density when writing continuous "ones" with a ½ mil head gap.

Causes of Reproduction Errors During Tape Life

DURING FIRST FEW PASSES slitter dust and foreign material produce transient nonrepeatable read and write errors which intermix with any permanent tape defect errors.

AFTER FIRST PASSES permanent errors should remain as the type of dropout. Read and write errors, if they develop, will be caused by poor tape handling which has damaged both the surface of the tape oxide and the edges of the tape.

NEAR END OF TAPE LIFE the heads will tend to cake. A head cake builds up from the oxide and binder layer of the tape and forms directly on the heads (and possibly on the tape guides). A head cake appears to be caused by heat and pressure due to scratches, surface depressions, or rough areas of the head.

THROW AWAY any tape which suddenly begins to exhibit poor reliability because of head caking. Such a tape should be considered permanently damaged. Cleaning the head will usually only temporarily relieve the situation. After caking starts, the oxide surface of the tape becomes rougher and softer than normal, and this surface condition accelerates reformation of the cake. This condition is more relevant to short repeated passes than to full-reel passes.

be considered as a direct function of a recorder's insensitivity to tape spacing dropouts, reliability is independent of tape packing density at any density below the pulse crowding point. Thus, operating any recorder at reduced packing density will not necessarily increase the reliability of reproduction.

On the other hand, the maximum reliability that the recorder can deliver does depend on the packing density, and reliability can be made higher at lower packing densities by making the elements that contribute to frequency response just sufficient for the packing density required. How this can be done is described later.

Multiple tracks limit pulse timing . . .

The discussion so far has considered the effects on recording reliability of single-channel packing density. Other factors are involved in multiple track systems. These factors limit the *maximum* packing density to something lower than that for single track systems, because of pulse timing requirements in associated parallel gating circuits.

Figures for the maximum packing density of multiple track systems derive from interchannel time-displacement tolerances. Write and read head gap scatter, dynamic skew, tape speed variations, pulse detection consistency, and clocking system design contribute to time displacements in mechanical and electrical forms. Time shifts can also occur when a pulse is recorded or read under conditions that are typical of a partial dropout.

Two general effects fall into the latter category. The first is caused by amplitude-sensitive pulse-detection systems, which can have detection time errors of approximately one-half the pulse width for an 80 percent pulse amplitude reduction. Poor pulse resolution during a dropout increases this error. (With the more common peak detection system, tape spacing will not produce any shift in detection point.)

The second effect is caused directly by tape spacing. The effective point at which the pulse is written on the tape shifts relative to the trailing edge of the write head gap as a function of spacing.

. . . but not reproducing reliability

All of these effects tend to decrease the maximum packing density practical for any multichannel recording system because of timing tolerances in associated circuits, but have little effect on the reproducing errors due to tape spacing dropouts. In fact, design approaches that increase the maximum packing density by decreasing sensitivity to interchannel time displacements will still deliver less than maximum reliability in applications where the high maximum packing density is not necessary—just as any single recording channel will.

Causes of signal dropouts

Tape signal dropouts usually fall into three categories:

- Permanent errors due to defects such as pinholes or oxide exclusions intrinsic in the tape that make a recorder repeatedly incapable of reproducing usable information
- Write errors due to nonrepeatable momentary loss of write head-to-tape contact during the writing process (tape spacing caused by foreign particles, tape surface defects, physical deformation

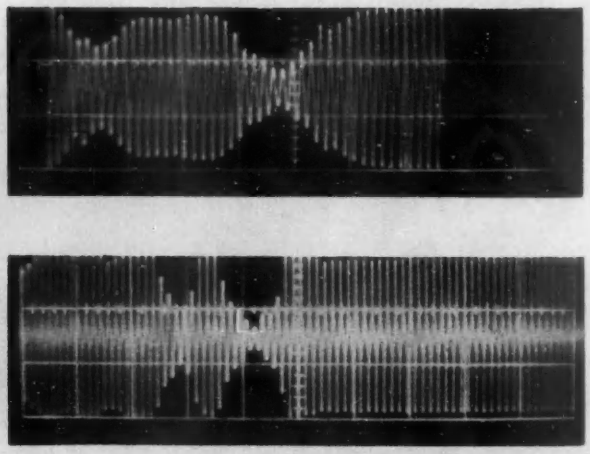


FIG. 2. Pulse envelopes from two different drop-out areas show similarity of envelope shape. Recorded packing density was 200 bits per in.

PANALARM RELIABILITY

of the tape, or poor tape handling)

• Read errors due to nonrepeatable momentary loss of read head-to-tape contact even though the correct information is still retained on the tape.

Momentary loss of head-to-tape contact is presently accepted as the major cause of tape errors throughout the life of a tape (see box). This is demonstrated by the characteristic shape of the envelope of output pulses through a dropout. With a pin hole or oxide exclusion that does not lift the tape from the head, there is a sharp change in output pulse height that lasts only as long as the defect is over the head. But the most common dropouts have the envelope shape shown in Figure 2, which depicts the gradual lift of the tape from the head in the area of the defect and its gradual return to close contact.

Dropouts resulting from head-to-tape spacing cause a decrease in amplitude of the signal recovered from the tape. This loss can be produced by a reduction in the strength of flux recorded on the tape, such as the drop-out spacings that occur during the write process. The loss can also occur if a correctly recorded tape is spaced during subsequent reading.

A read spacing loss results from two effects. One is a reduction in the amount of flux coupled to the read head because of the spacing between the head and tape. But most of the loss is caused by the reduction in high-frequency response which accompanies poor head-to-tape contact. The characteristic read-head output rises 6 db per octave, so any reduction in response to the relatively instantaneous step function of tape flux reduces the amplitudes of the most prominent frequencies in the pulse. In other words, as the tape is spaced farther from the read head, the higher frequency components contributing to the pulse amplitude are replaced by lower ones with lower amplitudes. The over-all effect produces a drop in amplitude of digital pulses until they can no longer be detected as valid bits, and hence become dropouts.

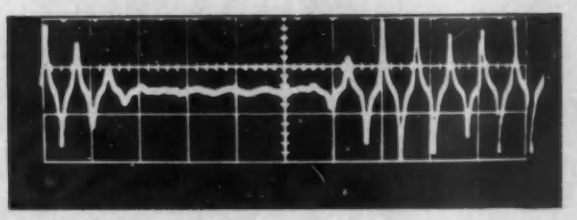
How to get maximum reliability

For a single-channel recorder, there is a specific maximum reliability, that is, a reliability capacity, for any given bit packing density. In multichannel recorders, the maximum packing density is limited by mechanical and electrical timing tolerances, and the reliability can never exceed the single-channel reliability. The problem then is one of raising the reliability of the system to capacity. In general this can be done by any technique that tends to destroy high-frequency response, pulse resolution, or single-channel maximum packing density. Such techniques increase the write flux intensity. Write flux greater than saturation substantially improves the ability of a recorder to write through permanent tape errors with better amplitude and resolution in the depths of a dropout, see Figure 3.

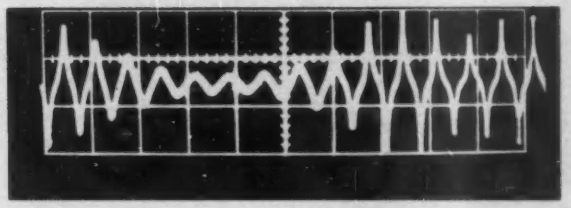
Some of the techniques that can be used to increase reliability toward capacity include opening of the head gap, reducing the bandwidth of the read detection system, and purposely operating the tape out of contact with the head. Tape spacing sacrifices resolution for insensitivity to head-to-tape separation, and will produce less change in signal strength and resolution of pulses during drop-out conditions.

Thus, single-channel reproducing reliability can be improved by using any real drop-out desensitizing technique such as increasing write flux strength, and reducing the effect of dropouts by purposely making the system respond poorly to normal pulses. Such improvements are limited because they degrade the performance of the read and write systems, which must be kept adequate to handle the digital data rate specified by the recorder application. But the result will be a digital recording system that operates near maximum reliability at the packing density specified.

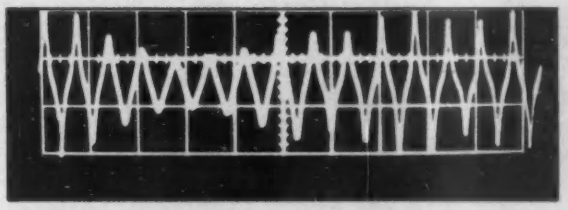
MORE RELIABILITY THROUGH SAME DROP-OUT AREA



A—Standard write head



B—Higher write current

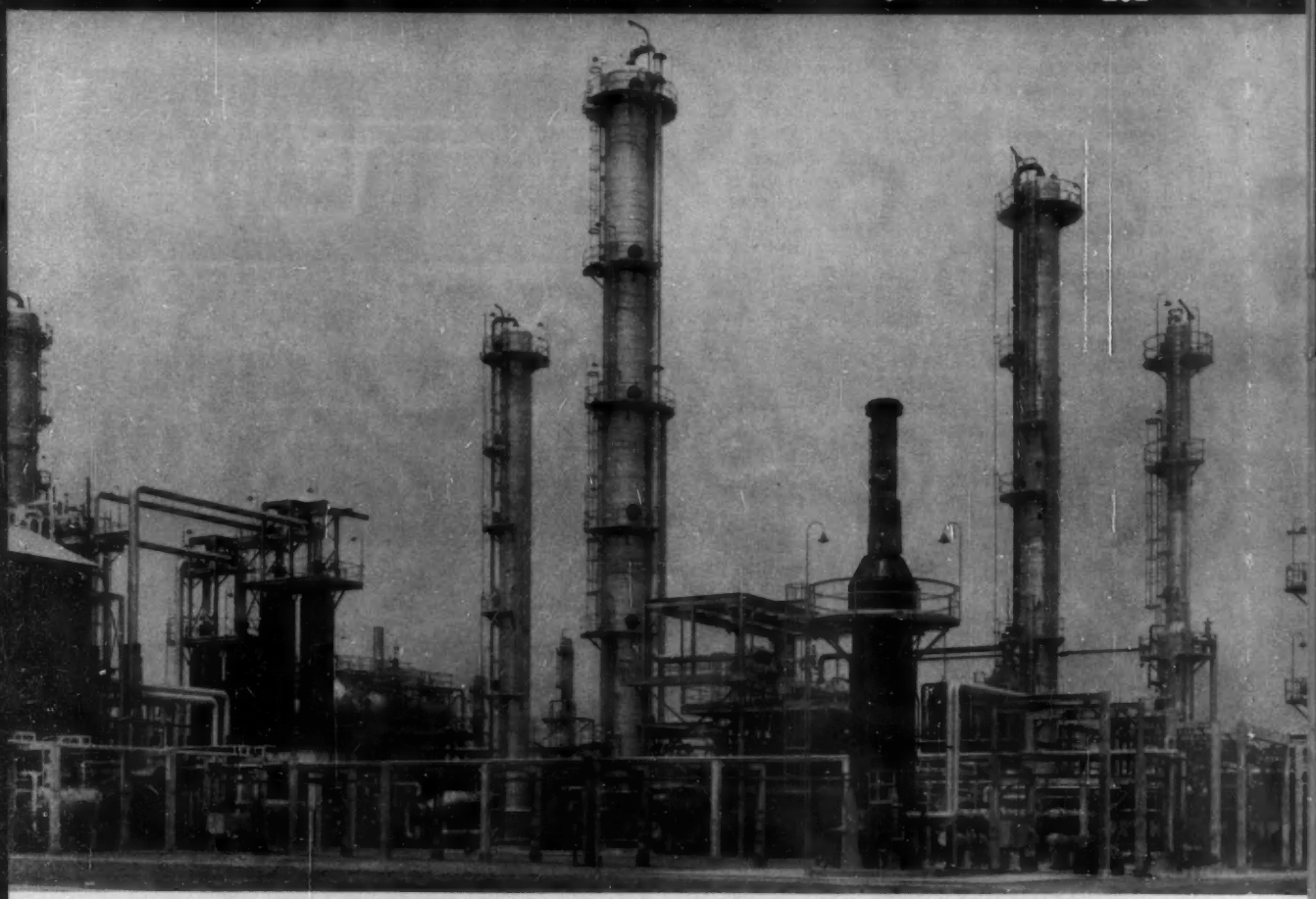


C—Plus wider head gap

A—Permanent drop-out read by ½ mil head gap and 75 milliamp write pulse.
B—Same drop-out area with same head but 150 milliamp write pulse
C—Same drop-out area with 1 mil head and 150 milliamp write pulse.

PANALARM® RELIABILITY

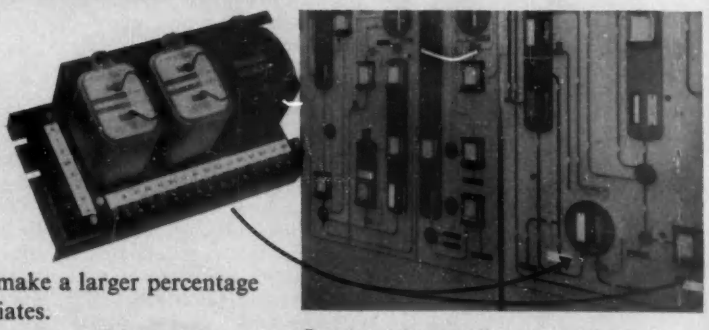
CHOSEN BY UOP AND SHELL



View of 16,000 BPSD PLATFORMING® unit at the Houston, Texas, Refinery of SHELL OIL COMPANY, licensed by UNIVERSAL OIL PRODUCTS COMPANY and designed in conjunction with Shell.

DEPENDABLE MONITORING SINCE INSTALLATION IN 1956

The Panalarm remote system is particularly suited for central graphic control panels used in most refining processes. Back-lighted nameplates are conveniently located in the process flow and actuated remotely by hermetically sealed alarm relays mounted in strip chassis or adapter cabinets. Meets Class I, Group D, Division 2 requirements.



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Counter Watches Out for Transients

R. N. MICHAEL
Locomotive and Car Equipment Dept., General Electric Co.

FIG. 1. Counters total transients that exceed pot settings.

Voltage transients only microseconds long can destroy the highest voltage transistors and semiconductor rectifiers now available. But detection is difficult with nonnal measuring devices, which are not very effective for voltages of short duration and whimsical occurrence. This portable six-channel transient voltage counter and level indicator, Figure 1, was adapted from a design by F. W. Gutzwiller (see G. E. Semiconductor Products Dept. Technical Paper 200.16). Typical applications include: 1) checking amplitude distribution of transients in circuits where semiconductors are to be applied, 2) determining effectiveness of protective or filter circuits, and 3) monitoring semiconductor tests for the presence of transients.

Each channel acts as a bistable switch with automatic reset. The user presets a threshold voltage (0-1,000 volts in the basic range) on a precision pot dial; if this voltage is exceeded for ½ microsec, the circuit actuates a counter and then resets. Maximum repetition rate is 20 cps. The instrument will operate unattended for five days on self-contained batteries, and maintains an accuracy of 3 percent from 0 to 150 deg F. The six 500,000-ohm inputs can be connected to different circuits or tied together and the pots set to various levels to get statistical amplitude data.

The circuit, Figure 2, uses a unijunction transistor, Q_1, to compare the input signal with a reference and trigger counter I_1. The input value at which Q_1 conducts is set by 10-turn potentiometer R_1, and the relationship between pot setting and the triggering voltage developed across R_6 is linear. The voltage to be monitored is introduced at the signal input jack and stepped down by a factor of 200 in the network consisting of R_6, R_7, C_3, and C_4. C_3 and C_4 maintain the dividing ratio at all frequencies.

Transistor Q_2 with zener diode CR_2 applies regulated 19-20 vdc across voltage divider R_5R_1. Battery voltage fluctuations do not affect instrument accuracy until the battery voltage drops below the avalanche voltage of CR_2. The push button "test" switch can be used to check operation of the trigger circuitry and counter.

When Q_1 conducts, C_2 discharges through CR_1, Q_1, and R_4 to fire the silicon controlled rectifier. The SCR actuates relay K_1, and K_1 energizes the counter and removes supply voltage from the SCR, resetting the circuit. Capacitor C_2 delays relay dropout sufficiently to prevent it from acting like a buzzer.

C_4 is trimmed by applying a 100 kc or higher frequency square wave to the signal output and adjusting until the waveform across R_6 has the same shape as the input waveform. If a variable high voltage supply is available, R_1 is best calibrated by feeding known voltages to the signal input jack. If only a low voltage supply is available, it can be connected to the calibration jack and its output multiplied by the divider ratio to find the corresponding input voltage.

Tests on the counter showed a maximum error of 20 volts—2 percent of full scale—for rectangular pulses from 1 microsec duration to dc. For shorter pulses the error increases, and for peaked waveforms the instrument reads the voltage level at which the pulse is approximately 1 microsec wide.

Separate 22.5-volt batteries (RCA VS102 or equivalent) are required for each channel. The static current drain is 4 ma, and the momentary trip current is about 120 ma. A 6-volt lighting battery (Eveready 510S or equivalent) operates the counters on all six channels and has a life equal to three sets of the individual 22.5-volt batteries.

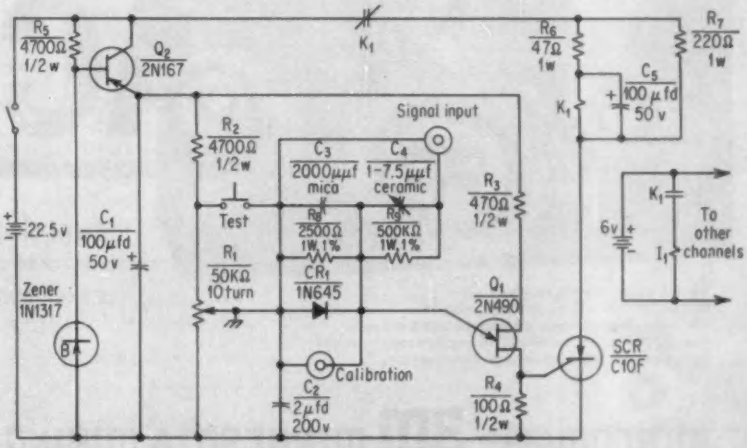
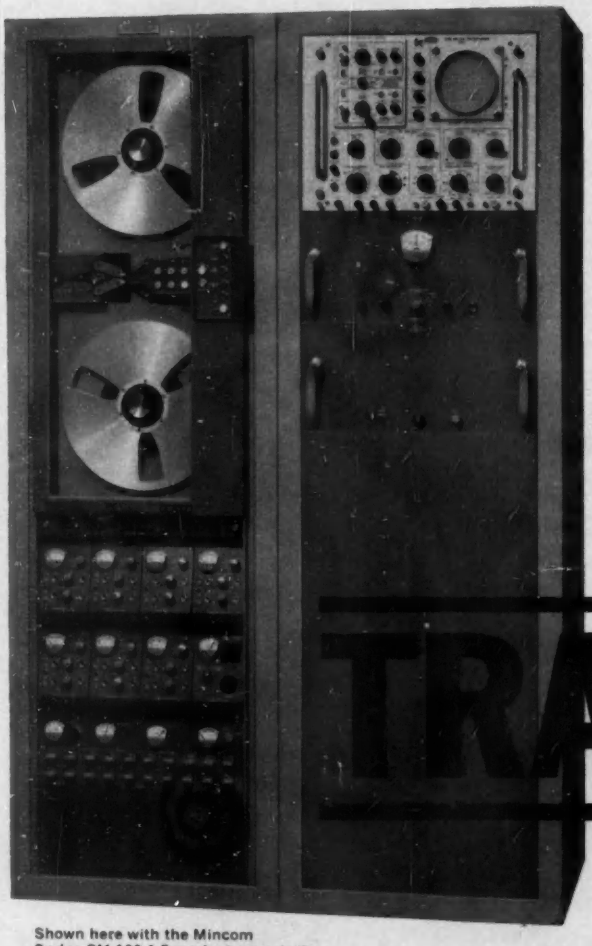


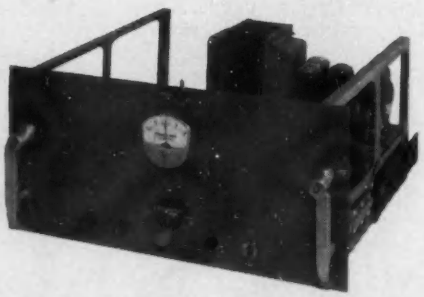
FIG. 2. K_1 is dpdt relay with 12-vdc coil; I_1 is a 6-vdc counter. Other five channels are identical.

Data loss due to drop-outs is eliminated in FM predetection recording-reproducing by Mincom's new, exclusive Tracklok®

This is because, for the first time in the field of instrumentation, the **Tracklok** makes possible redundant FM data recording at the carrier level. In any desired FM or PM-type carrier system, data loss is eliminated by a 99% skew reduction; existing skew of ± 0.3 μs for example, is effectively reduced to ± 0.003 μs, a reduction of 100 to 1.



Shown here with the Mincom Series CM-100 1.5-mc Instrumentation Recorder/Reproducer, a standard auxiliary rack houses (from the top down) an oscilloscope monitor unit, the new **Tracklok**, and a demodulator.



The Tracklok

Completely Compatible: The new **Tracklok** is designed to improve the predetection performance of Mincom's 1-mc Series CM-100 Instrumentation Recorder/Reproducer (which now, on special order, performs to 1.5 mc at 120 ips). **Tracklok** can be incorporated into all existing Series CM-100 systems, since it is compatible with CM-100 or any comparable recorder-reproducer in the standard IF carrier frequencies.

TRACKLOK®

Reliable Simplicity: The same reliability that has been typical of Mincom's instrumentation systems for years has been built into **Tracklok.**

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Cam Valves Align Wheels of Giant Crane

GLEN T. HOLEN
Travelift Div., Drott Mfg. Co.

The rubber tired steering wheels of the 50-ft wide crane in Figure 1 could not be connected mechanically, but an inexpensive hydraulic system keeps them aligned to reduce tire wear and minimize stresses.

Steering cylinders at each wheel, Figure 2, are connected in series and controlled by a four-way steering valve. Initial alignment is done by adjusting the volume of oil in the line connecting the cylinder rod ends. If this volume changes due to leakage or temperature variation, the circuit admits oil to or bleeds oil from the line.

Cam valves are mounted on the Travelift frame at each steering wheel and stroked by cams mounted on the steering wheel pivots. When the wheels are in alignment and pass center position the cam valves shift simultaneously, and nothing happens. If one wheel passes center position before the other, oil is admitted to or bled from the steering line (depending on the direction of wheel motion and which wheel is leading). This happens each time the wheels pass dead center until alignment is established.

The crane, which can carry 50-ton loads at 100 ft per min, was built for United Technology Corp. to transport large rocket motor segments. Engineering was by R. A. Stearn, Inc., of Sturgeon Bay, Wis.

FIG. 1. Steering wheels could not be mechanically connected.

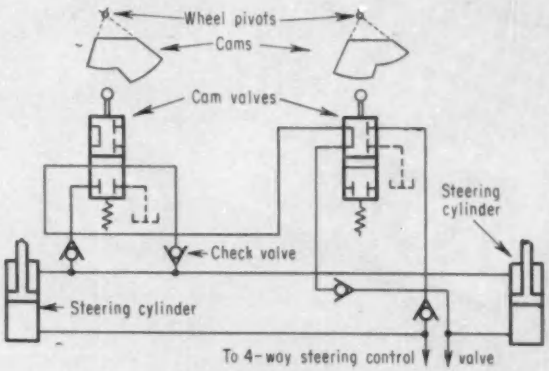


FIG. 2. Cam valves adjust oil in steering line each time wheels pass dead center.

Eddy Currents Check Tubing On-Line

H. N. NERWIN
Magnaflux Corp.

The manufacture of electric weld tubing is a continuous process where sheet stock of proper width is fed through forming rollers and a welding mill. A nick, extreme oxidation, or dirt on the edge of the sheet can cause a void, poor weld, or other defect at the weld zone. Also, chips or other foreign particles picked up on the forming rolls can damage the tubing surface, so some form of inspection is a must.

Generally the mill operator slices out an occasional section of tubing and subjects it to flaring and bending tests. Except for a submerged air test to check each length for leaks, the complete product is not inspected.

Magnatest SD-100 Series equipment inspects steel tubing continuously and rejects any imperfect sections. On its way to the cutoff table, the tubing passes through a pair of balanced, differentially connected coils, Figure 1. These coils are excited by an oscillator and buffer amplifier, Figure 2, and are also part of a bridge circuit. A defect under one of the coils changes the impedance of that coil, unbalances the bridge, and gives an output signal.

The differential coil arrangement helps eliminate background noise due to diameter, conductivity, and temperature variations in the tubing. Permeability variations are suppressed

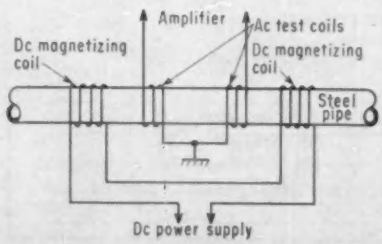


FIG. 1—Dc field suppresses permeability variations; differential coils induce eddy currents.

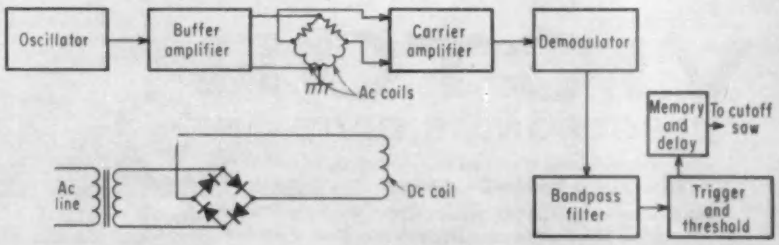
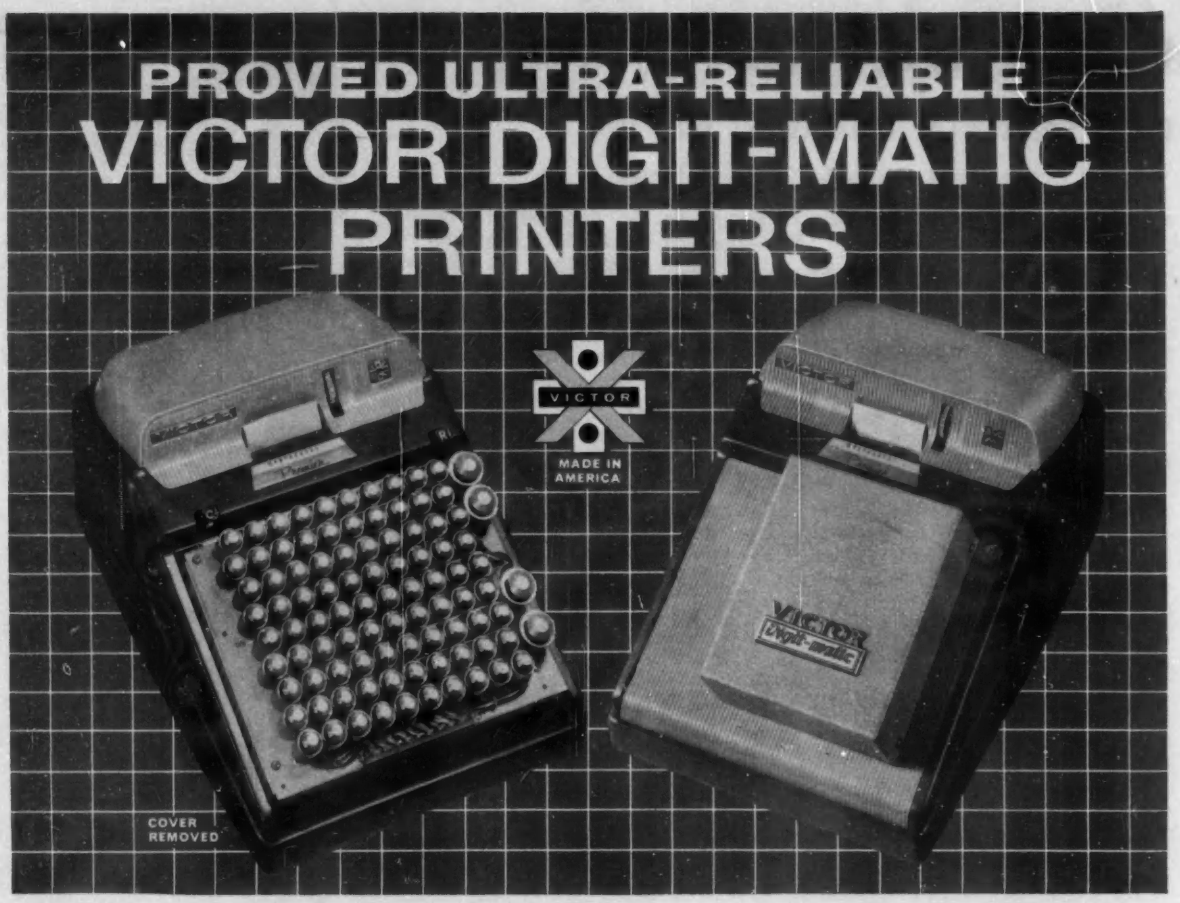


FIG. 2. Defect signal from bridge triggers cutoff saw.

PROVED ULTRA-RELIABLE VICTOR DIGIT-MATIC PRINTERS



160,000,000 digit impressions without failure

Rugged, Trouble-Free—Digit-Matics are specially built to stand the strain of continuous operation. In a durability test, over 160 million digit impressions were made without breakdown or need of adjustment. The machine tested operated continuously, eight hours per day until 160 million digit impressions were made. During this period only normal lubrication and cleaning were performed.

Parallel or Serial Entry — Automatic and unattended, solenoid-activated Digit-Matics print out alpha-numeric data from remote equipment. High speed parallel entry models accept up to 10 digits at a time, print up to 4 lines per second. Serial entry models accept 1 digit at a time, up to 11 per line.

Two-Color Printing — Positive values in black, negative values in red. Ideal for "accept-reject" sequences, testing applications, accumulating data from two sources on one Digit-Matic, and many other uses.

Adaptable to Your Specific Needs — Line includes listers, accumulators and calculators. Versatile units can handle degrees, minutes, seconds, fractions. Other modifications: superimposed keyboard for manual use, time readings, counters, etc.

Immediate Field Service — 70 factory service branches and service representatives in over 600 cities assure uninterrupted operation. Victor offers 30-day delivery on most Digit-Matics. Mail coupon now for product data and application information.

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by applying a high level dc field at the point of inspection. This reduces the permeability to a value approaching that of air.

The bridge output is fed through an amplifier, demodulator, and a tuned bandpass filter that further discriminates against unwanted information such as diameter changes. Next comes an amplitude selective circuit that passes only signals that exceed a preset level. As soon as this circuit is triggered, a warning light flashes, and the information is registered in a combination time delay and memory system that delays the first cutoff signal until the defect is just behind the saw. Later it supplies a second signal to cut the tubing just behind the defect.

Where defects generally occur some distance apart, a simple RC circuit provides the single time delay required. For more complex applications, a shift register or magnetic drum can remember many defects and control cutting accordingly.

The equipment, Figure 3, operates satisfactorily at any tubing speed between 25 and 800 ft per min and accommodates tubing from $\frac{1}{8}$ to 4 in. in diam. Different coil assemblies are installed for different tubing sizes, and an integral bridge is provided for balancing them.

FIG. 3. Tubing feeds through coil assembly at 25-800 ft per min.

Dipping Chromatograph Tube Collects Microgram Samples

R. C. PALMER
Griffin & George Ltd.,
London, England

Chromatographs using capillary columns require more precise sample injection systems than chromatographs with packed columns. Capillary columns demand samples measured in micrograms, compared with the normal packed column sample of 1 milligram for liquids—equivalent to about 1 cc of gas. Liquid syringe injectors or gas loop switching handle larger samples without difficulty. Normal practice with capillary tubes is to use one of these techniques with splitting devices to reduce the sample size. But gas or liquid impinging on the hot splitters causes explosive pulses, and this effect, coupled with fractionation at the splitter plates, often makes the sample quantities actually entering the capillary column indeterminate.

The system pictured in Figure 1 injects microgram quantities of gas directly into the capillary tube. It was developed for use on the Chromatoscope, a new high speed, CRT display instrument in which high repeatibility of sample size is essential. Figure 2 shows how a solenoid moves the capillary tube inlet from a 100-percent carrier gas region into a 100-percent sample region. The dwell time in the sample region determines the size of the sample slug; this can be varied from 0.4-0.5 microgram to ten times that amount. Rectangular samples with rise times around 4-6 millisec and decay times only slightly longer can be injected.

Carrier gas enters the $\frac{1}{16}$-in. diam mixing chamber through the upper inlet; the sample stream enters from below. A central 0.02-in.-high annular exit exhausts to atmosphere through a reducing valve and simultaneously pressurizes the capillary tube inlet. Carrier gas and sample mix in a 0.5-1 mm long region at the middle of the chamber. When the solenoid is pulsed, it moves the capillary inlet down from position P to Q, 4.5 mm below the mixing zone and saturated with sample gas.

Carrier diffusion into the bottom section and sample diffusion into the upper region are eliminated by adjusting the flow rates through the mixer unit. The formula $C = C_0^{-XV/D}$ gives the concentration at any distance X back against a linear stream with velocity V and diffusion constant D (on the order of 0.1 sq cm per sec for gases). Diffusion effects become negligible within 0.3 mm of the exit point, and the capillary tube passes through this indeterminate mixture zone in 1 millisec. Sample repeatibility depends only on solenoid action.

An added feature is the glandless connection between the capillary column and the mixer unit. The normal 0.03-in. o.d. capillary is made a sliding fit within the upper end of the mixer. The only leakage is a slight bleed of inert carrier gas from the upper portion of the mixing column.

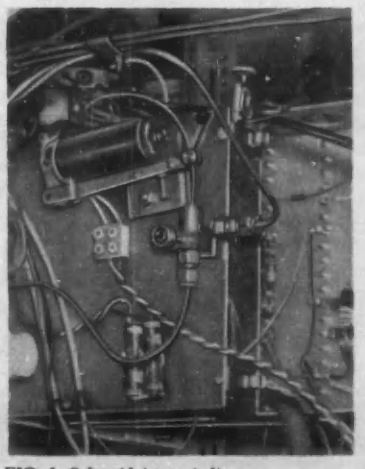

FIG. 1. Solenoid (at top) dips capillary into sampling chamber.

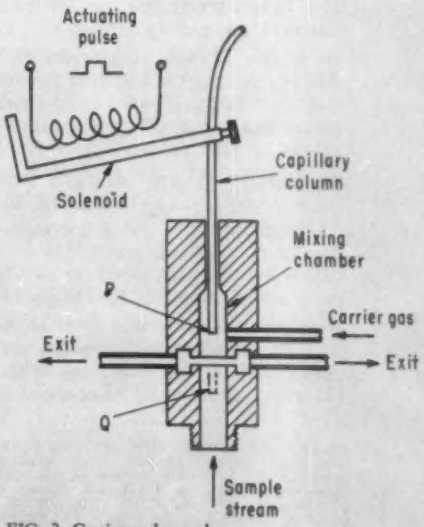

FIG. 2. Carrier and sample mix in center of chamber.

Here lie 707 rolls of paper tape shot full of holes by Tally Perforator #171

...Long may she run!

LIFE TESTING PROVES RELIABILITY OF TALLY READERS AND PUNCHES

The only way to really find out if a machine is reliable is to run it to death. That's what Tally engineers are literally doing with perforator #171 as part of a continuing program to prove and improve the accuracy and reliability of Tally tape equipment.

On October 20, 1960, perforator #171, chosen at random from a production run, started a life test with an alternate hole pattern verified by a Tally reader.

As of Feb. 13, 1961, perforator #171 had completed 70,700,000 cycles of accurate operation with only two minor mechanical break-downs. Repairs were made in a matter of minutes. This is a record of reliability that speaks for itself.

RELIABILITY IS ONE REASON TO CHOOSE TALLY

"State of the art" technical excellence is another. Only Tally punches give you the benefit of asynchronous operation. Speed is completely variable. A unique wire clutch lets you vary speed for slaving to other equipment which simplifies the design of logical systems.

Tally punches are priced from $1,000. Standard perforators operate at 60 characters per second and will punch 5, 6, 7, and 8 channels without modification. On special order up to 32 channels are available.

Only Tally readers give you the benefits of "full bit accountability." Using Form C switching, you get positive sensing of the presence or absence of holes. Reading rate is 60 cps in either direction – instantly reversible for rapid search and select. Readers have triggered tape feed readout with the rate controlled by external equipment. Reader prices begin at $595 for standard units capable of reading 5, 6, 7, or 8 channels without modification.

FOR A DEMONSTRATION OR MORE INFORMATION

You may arrange a demonstration or secure full technical information by calling your nearest field engineering office listed below or writing directly to factory.

P.S. *If you are having problems making complex multichannel programming tapes, call us about that too. We're making up 16 channel guaranteed error-free tapes for some of the nation's most sophisticated missile and satellite programs.*

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10

Controller Combines Electronic Sensing With Pneumatic Output

LESLIE R. AXELROD
The Powers Regulator Co.

The proportional controller developed by the Powers Regulator Co. turns temperature data from one or more thermistors into a pressure signal to operate heating or air conditioning equipment. Figure 1 is a block diagram of a single point control system using one thermistor to monitor room temperature T_1. The resistance of this thermistor is compared with the resistance of a setpoint potentiometer in a dc Wheatstone bridge.

Summing is accomplished using multiple input windings on a magnetic amplifier. The amplifier output is connected in push-pull; the differential output current drives a novel transducer and is also fed back to the amplifier input to compensate for the dead zone of the transducer. Without the rate feedback of this minor loop the system would oscillate and never maintain a setpoint.

The transducer, Figure 2, is an air valve mechanism operated by a differentially wound electromagnet. It has three positions—supply, neutral, and exhaust—that depend on the polarity of current through the electromagnet. The output pressure signal from the transducer goes to a pneumatic operator (valve or damper motor) and to a bellows in the feedback unit. This bellows and an adjusting spring position the armature of an E-I differential transformer. The spring is set so that the armature is in mid position when the control pressure equals 8 psi.

An excitation voltage is applied to the transformer primary, and the output from the secondary is proportional to armature position. This output is demodulated and fed back through a sensitivity control to an output winding on the magnetic amplifier, forming a proportionality loop.

As long as $T_1 = T_s$, the setpoint temperature, the bridge output and the differential output of the amplifier are both zero, and the transducer stays in neutral position. Assuming the control pressure is 8 psi, the feedback unit is also in mid position, and the feedback voltage is zero.

If room temperature T_1 increases, the thermistor resistance drops, and there is an output voltage from the bridge and differential current in the amplifier output winding. This actuates the transducer, opening the supply valve. The increased control pressure forces a valve to close and reduces the steam going to a heating coil.

As the control pressure increases, the feedback unit armature moves from its center position. The air gaps are no longer equal, and the net flux linking the secondary induces a voltage that is fed back to the summing point. The pressure continues to increase until the feedback voltage is equal and opposite to the output of the bridge. Then the error signal into the amplifier is zero, and the transducer returns to neutral position. As the new valve setting starts decreasing the temperature, opposite actions occur until finally the temperature is restored to its setpoint and the control pressure is returned to 8 psi.

When the sensitivity pot is set so that minimum voltage is fed back to the summing point, a large pressure change is required to buck out the voltage developed by the bridge in response to a temperature change. When the pot is set for maximum feedback, little pressure change is needed to buck out the bridge voltage and return the transducer to normal.

In master-submaster and averaging operation, three bridges are paralleled ahead of the summing point. Two thermistors check fan discharge and outdoor temperatures; the room temperature bridge has a fixed resistor or a third thermistor.

FIG. 1. Three loops provide temperature comparison, dead zone, and sensitivity adjustment.

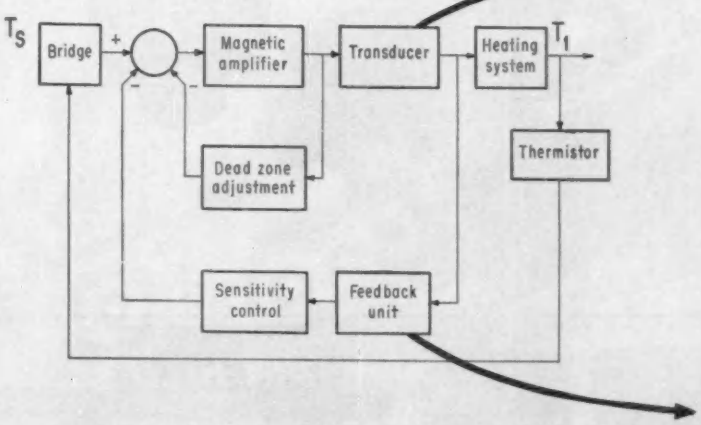
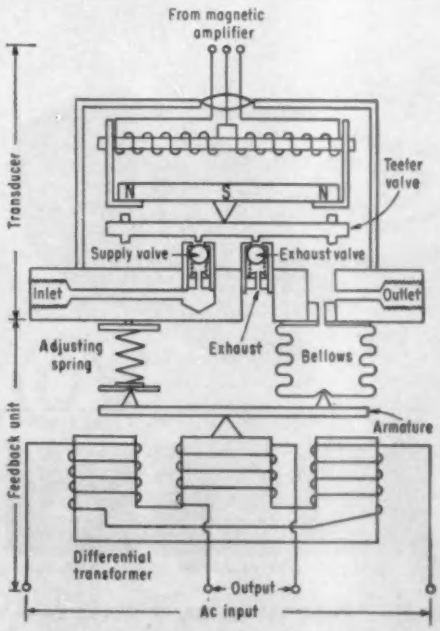


FIG. 2. Output pressure signal sets armature of feedback unit.



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Out of continuing research in solid state has come the 3S-G family of silicon-semiconductor strain-gage pressure transducers *with accuracy as high as ±.003% FS/Deg. F* and the new Fairchild d.c. differential amplifier for transducer applications. Tough, tiny, and extraordinarily accurate, the transducers offer the best characteristics of strain-gage and potentiometer-type transducers plus the advantages of piezoresistive silicon-semiconductor sensing elements. ■ Fairchild 3S-G transducers have infinite resolution, self-contained calibration, unexcelled repeatability, and extremely high output signal. Internal temperature compensation from zero to 150° F is standard. Compensation over entire operating temperature range from — 65° F to 250° F is available on special order. Designed for new systems and interchangeable with existing military and industrial instruments, they will operate in practically all gaseous and liquid media. Pressure ranges are from 0-10 through 0-10,000 p.s.i.g. or p.s.i.a. Accuracy is as high as ±.003% FS/degree F (error band). Combined linearity and hysteresis is as good as .05% terminal. Standard output is either 50 mv. or ¼ v. or 5 v.d.c. (5 mv. to 5 v. available). The higher output range is especially valuable for transmission over a long line without additional amplification. ■ The Fairchild family of 3S-G pressure transducers includes low-pressure gage and absolute, high-pressure gage and absolute, and high-line low-differential instruments. In addition, there is a zero-drift solid-state d.c. amplifier. Absolute and gage transducers are available in ruggedized and airborne versions. Suppressed or offset ranges are available in all transducers. All have significant applications for precise measurement, testing and control of pressure in underwater, ground support, and airborne systems. All are available from stock for immediate delivery. ■ For more information about Fairchild 3S-G pressure transducers, write Dept. 52CE.

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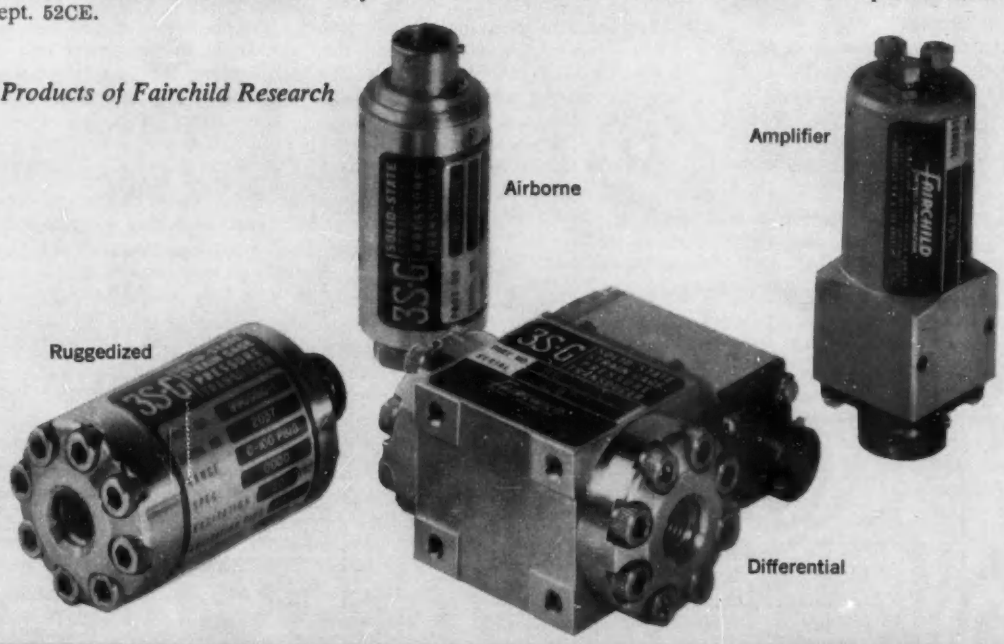

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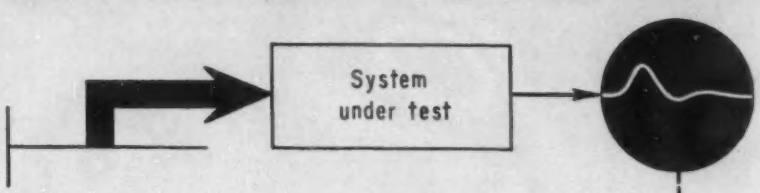

ANALYZER FINDS RESPONSE DATA
based on simple input.

This analog computer-test device produces frequency response plots at low cost without requiring specially trained personnel. Only 2 min are required to produce a plot from impulse response data.

For testing, a unit step function is applied to a system, and the response is inserted into the analyzer through a mechanical plotting board as in the figure at right. The device computes the frequency response function over three decades and drives a plotter to produce the results directly in terms of magnitude and phase angle. Decades are normalized so that they can represent any frequency band required. The time required is short enough to allow on-site determination of process stability, control system parameters, and effect of process changes.

For nonlinear systems the unit permits analysis by the describing function method. Results of a series of sinusoidal inputs to the nonlinear system can be fed into the computing unit, and the describing function will be obtained as a series of plots of magnitude and phase angle at various frequencies.

The standard model (M-101-A) is supplied with plotter and separate power supply (not shown here) for $9,100. An auxiliary device is available to convert test signals to standard 10 to 50-ma or 3 to 15-psig signals for direct coupling to a control system.—Procedyne Associates, Inc., Perth Amboy, N. J.

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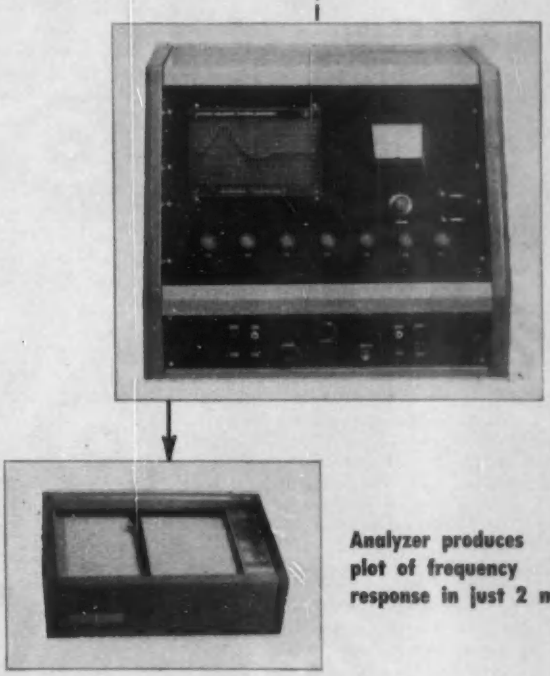
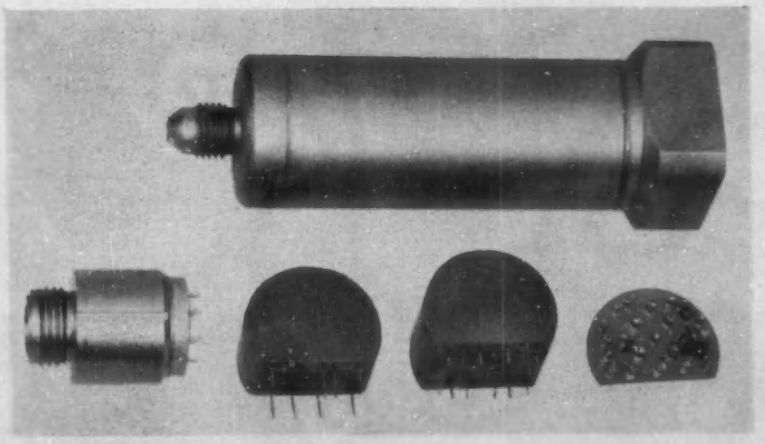


Analyzer produces plot of frequency response in just 2 min.



TRANSDUCER produces 5-volt output.

A new solid state power supply and high performance amplifier are used in this high output (0-5 volts) transducer. Components shown in photo are, l to r, sensing element, power supply, amplifier, terminal board. Sensing element now available is for pressure, but an interchangeable acceleration module is planned.

The power supply, which along with the amplifier is mounted within the unit's 4-in. long by 1⅛-in. diam case, eliminates the need for a special regulated supply. A 28-vdc source can vary

Advertisement

WHY CALIBRATE?

Calibration may be defined as the comparison of an instrument against a standard of measurement of like kind. Essentially, this states that a given set of parameters is measured by both the instrument being calibrated and by the instrument against which the comparison is made. When the accuracy of the calibration standard is known then it is possible to determine the accuracy of the instrument being calibrated.

Present technology advances have brought about increasingly complex parameters of measurement which, in turn, have increased the requirements for calibration accuracies to that point where the methods used a few years ago will no longer suffice. The accuracies now required in most instances demand, not only very accurate calibration of the measurement instrument itself, but also the system in which the instrument is installed. System calibration has become a requirement because the system contributes significant effects to the measurement instrument installed in it. This also indicates that in-place, system, calibration is proper, indeed necessary, in many cases.

An outstanding example of the necessity of in-place, system, calibration can be found in jet engine, or rocket motor, test stands. Measurement instruments used in these stands are, when calibrated separately and in the laboratory, subjected to a very different set of environmental conditions than when operating in the stand, itself. Further, the actuating of the instruments, and the effects surrounding this actuation, will cause the measuring instruments to react accordingly, sometimes injecting unforseen errors into the total system.

Why Calibrate? Calibration in its best form is assurance that test results will be traceable to known standards of measurement and will assure the accuracy of that measurement within well defined limits.

***General Metrics Company* specializes in providing assistance with your calibration problems. Highly experienced engineers, scientists, and technicians are available to establish approved calibration techniques, design and install calibration programs including the training of personnel at all levels, or to design, manufacture, and install Calibration Standards and systems to meet special requirements.**

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NEW PRODUCTS

by as much as 2 volts without affecting performance. Supply also isolates the sensor from ground, eliminating the common mode problem.

Amplifier exhibits thermal drift of only 1 microvolt per deg C, compared with 20 times this figure for other available units. In addition, coupling of amplifier and sensor in same package allows a better combined characteristic.

Linearity is to within 0.05 percent of full scale, with hysteresis and repeatability figures of the same order. Using a 1,000-psi sensor, the amplifier can provide resolution to within 1 psi; using best available recording techniques, 0.1 psi can be had.

Unbonded wire strain gage is used as sensing element, and all semiconductor elements in power supply and amplifier are welded and potted for high reliability.—Consolidated Electrodynamics Corp., Transducer Div., Pasadena, Calif.

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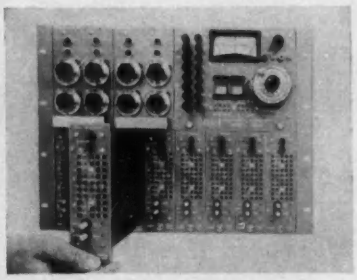
SYSTEMS



ITERATIVE COMPUTER

Compact modular design and components accurate to within 0.01 percent are features of this new 3200 Series iterative analog computer. Nominal size of the computer is 50 amplifiers but two or more computers may be slaved together. Inverter bandwidth is 1 Mcps, amplifier noise is 500 microvolts, and drift is 20 microvolts. All components are housed in 2 x 7 in. slide-in modules. Pushbutton selection is provided for compute, hold, reset, automatic recycle, slave, audible overload indication, and automatic hold modes and for meter sensitivity. —Donner Scientific Div., Systron-Donner Corp., Concord, Calif.

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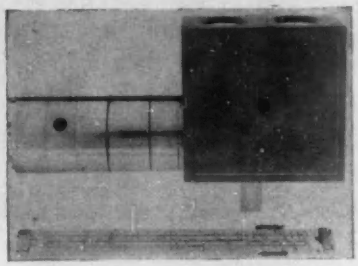

PNEUMATIC ANALOG

A low cost building block approach is used in this APAC pneumatic analog computer. Standard 3 to 15-psi pneumatic signals are accepted to add, subtract, multiply, divide, take ratios, extract square roots, integrate, and differentiate. Unit will also serve as a function or test signal generator and will provide memory. Use of common components is said to allow flexibility at low cost. A typical four-function module should sell for about $500.—Garrett Corp., AiResearch Manufacturing Div., Phoenix, Ariz.

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GAS ENGINE CONTROLLER

Optimum performance of gas engines in all types of weather conditions is possible with a new computer control system. A supervisory panel, a speed control network, and a pneumatic computer control speed and fuel-air mixture. Operator sets desired speed and mixture at a selector station, and a tachometer differential fuel regulation network controls speed while a multipoint programmed computer control network maintains mixture. Price: about $2,000.—Bailey Meter Co., Cleveland, Ohio.

Circle No. 313 on reply card

DATA HANDLING & DISPLAY

FAST DATA TRANSMITTER

Capable of operating at speeds up to 62,500 characters per sec, this new 1945 magnetic tape transmission unit has now been made available for telephone data links. A remote tape reading control unit, the 1945 is designed to operate with the manufacturer's 729 tape drive. For transmitting, a computer controls a remote tape unit by means of voice frequency tones. On receipt of a go signal, the transmit tape is set in motion. Information on the tape is sensed by dual-level circuits and transferred as seven parallel bits

Communications versatility at your fingertips

With Teletype Model 28 printers your messages and data can be sent quickly and economically to any destination, near or far. But this is only part of the story—these printers offer an array of optional features that can multiply the usefulness and versatility of your communications system, save you important time and effort. Here are examples:

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Teletype equipment is manufactured for the Bell System and others who require the utmost reliability from their data communications systems. For further information write to Teletype Corporation, Dept 21K, 5555 Touhy Avenue, Skokie, Illinois.

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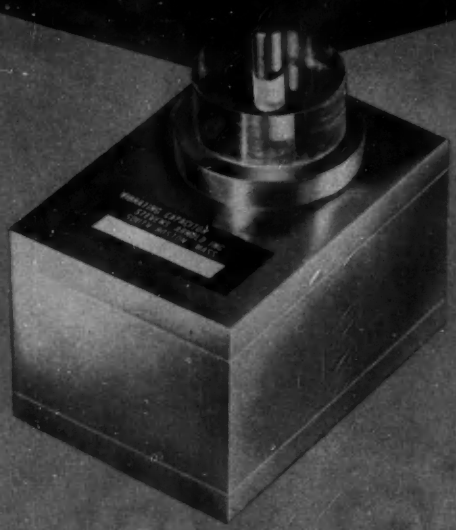

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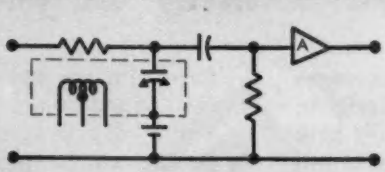

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NEW PRODUCTS

to the broadband transmission channels. When receiving, the 1945 accepts parallel data signals, amplifies them, and enters them into a computer through an adapter. Monthly rental rate for the 1945 (two are required for a data link) is about $1,100. —International Business Machines Corp., Data Processing Div., White Plains, N.Y.

Circle No. 314 on reply card

MODULAR RECORDER

Featuring plug-in design, this 300-kcps laboratory recorder/reproducer is designed for quick system expansion or reorganization. Replacement of the entire chassis is limited only by the time required to change the cabling. Besides directly recording and reproducing at 300 kcps, the FR-100C provides FM and PDM recording with FM response to 20 kcps.—Ampex Corp., Redwood City, Calif.

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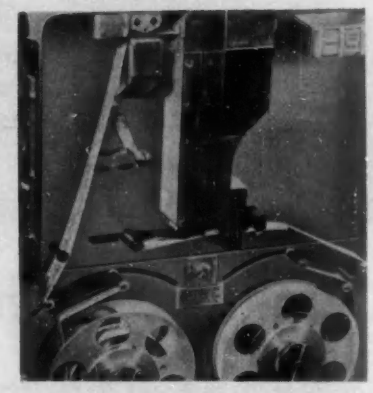

ELECTROSTATIC RECORDING

High recording speeds are the result of the Omni-Data's unique paper tape recording scheme. The recorder electrostatically records permanent visible spots on the tape instead of punching holes through the paper. The recorder accepts standard data pulses (−12 volts for a mark and sprocket, 0 volts for a space) and records spots in the same code as on punched tape. Unit has own power supply, tape drive, and controls. It will handle up to eight information channels and a sprocket channel to record on tape widths of $\frac{11}{16}$ − 1$\frac{1}{4}$ in. Recording speed is up to 600 characters per sec with units for 2,000 characters per sec operation now under development. Price is $7,584.

10 years without periodic maintenance!

The reed relays in the new Cubic V-70 series of digital voltmeters assure you of a decade of flawless service. These relays (which replace the stepping switches used in conventional DVMs) have been life-tested for 100 million operations—the equivalent of over ten years of normal operation. The V-70 covers the full DC range from 1 millivolt to 999.9 volts. Balance time is 500 milliseconds; maximum readout time, 750 milliseconds; absolute accuracy is 0.01% plus or minus 1 digit. The meter has no vacuum tubes or moving parts; it operates in any position and is heat and shock resistant; the relays require no maintenance. The V-70 series offers the highest operating speed available in its price range: V-70, only $1,580; V-71 (with automatic ranging and polarity), $2,200. For further information, write to Department **CT-109.**

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The new Atcotrol 305B incorporates the results of over 6 years of field experience in the control of timed industrial processes, laboratory and machine automation. Never before has an *automatic reset* timer been introduced with so much *proof* of reliability.

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Internal and external electrical connections on terminal block where they belong . . . 14 terminals provide complete circuit flexibility.

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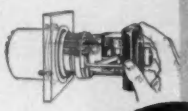
Provides flush mounting with recessed knob and dial. Timer setting may be Key-locked to prevent unauthorized tampering . . . optional feature.



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NEW PRODUCTS

Omnitronics, Inc. Sub. of Borg-Warner Corp., Philadelphia, Pa.
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PLUS . . .

(317) **Minneapolis-Honeywell Regulator Co.'s Electronic Data Processing Div.**, Wellesley, Mass., has announced four models of a magnetic disc **random access storage unit** for its 400 Series computer . . . (318) Featuring conversion rates of up to 10,000 per sec, a **conversion system** for digitizing analog information for direct entry into computers has been made available by **Monitor Systems, Inc., Sub. of Epsco, Inc.**, Ft. Washington, Pa.
Circle No. 317 or 318 on reply card

RESEARCH, TEST & DEVELOPMENT

TRANSISTOR TESTER

The new DY-5844 is designed to automatically measure the elapsed time between any two points on a high speed waveform in the testing of transistor delay, rise, storage, and fall times. Similar measurements can be made on diodes, magnetic cores, and other high speed components. The unit can also be used to measure pulse amplitude, area, and stored charge and for general purpose time interval measurement in the nanosecond and microsecond ranges. Accuracy is to within ±4 percent of full scale, ±0.4 nanosec. Price ranges from $8,000 to $12,000.—Dymec Div., Hewlett-Packard Co., Palo Alto, Calif.
Circle No. 319 on reply card

RELAY TIMER

Said to be the first of its kind, this digital timer is expected to be useful in measuring critical time characteristics of relays. Unit consists of a pre-

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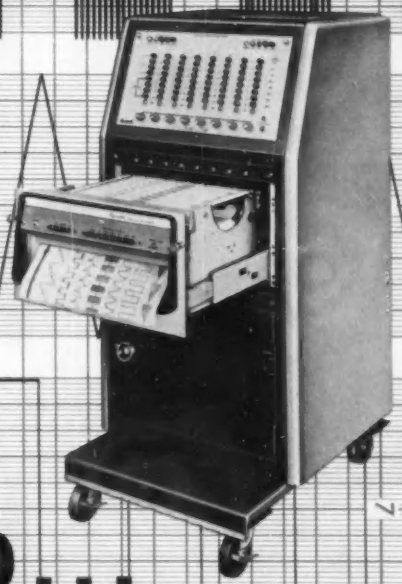

unmatched peak in penmanship...

The totally new Brush Recorder Mark 200 made these incredibly crisp tracings. No other recorder in existence can match them. Note the line width. It never varies . . . regardless of writing velocity, regardless of chart speed. The writing mechanism is electrically signaled by the position-seeking "Metrisite" transducer . . . no parts to wear, infinite resolution, verifiable dynamic ½% accuracy. Traces are permanent, high-contrast, reproducible . . . on low cost chart paper. The Mark 200 has but three standard controls . . . attenuator, pen position, chart speed. Such fidelity, simplicity and economy are possible with no other direct writing recorder. Write for details . . . they'll speak for themselves.

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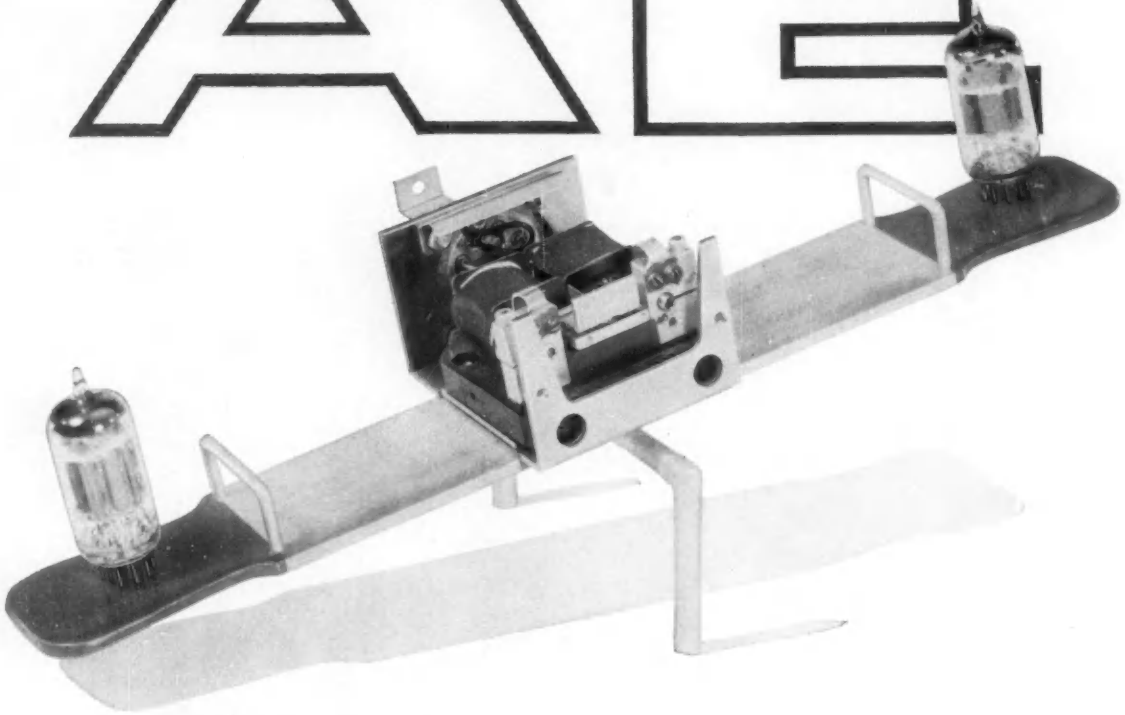


To the Engineer

looking for a fast circuit seesaw

If you're in need of something better than a flip-flop that only *partially* transfers a circuit —something with a transit time of less than a millisecond—then you'll be delighted with AE's Series PTW Polar Relay. This magnetically biased relay will transfer a circuit with the beautiful regularity of an observatory clock, and trigger on only a few mils from your available energy source.

Substantially smaller than other polar relays, the PTW's unique design virtually guarantees the high-speed switching of a single circuit *billions of times without readjustment!* Its service records to date in telegraph and teleprinter circuits and differential controls suggest that its life is practically limitless. Terminals to meet your specs.

Our circuit engineers will be happy to work with you in adapting the PTW to your designs. Or possibly you'd like to leave the switching to us—in which case we can take on the complete packaging and more than likely shave your costs.

For full information on the PTW, ask for Circular 1821-E – *and* for answers to your control problems, write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois.

AE CAN DO

AUTOMATIC ELECTRIC

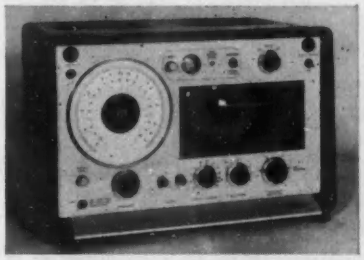
Subsidiary of

GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM

cision time reference, digital counter, digital integrator, logic circuitry, and necessary controls and displays. Operate, release, and bounce time can be measured for relays of up to six poles and with A, B, C, and D contact forms. Full scale accuracy is to within ±0.05 percent. Contact current levels are 0.1, 10, and 100 milliamp at 30 vdc. Price: $2,295.—Leach Corp., Compton, Calif.

Circle No. 320 on reply card



GENERATES ANY WAVEFORM

Generation of complex VLF waveforms is simplified in the SG.88 generator by a unique optical-mechanical system. Interchangeable transparent rotating discs are printed with an opaque pattern representing the total function and scanned by a narrow light beam. Output of this system replaces the conventional oscillator circuit. The disc's direction of rotation can be reversed to change the time sequence of the waveform. Frequency of the output signal is continuously variable from 0.005 to 50 cps. Frequency calibration is accurate to within ±1 percent of full scale. Unit is manufactured by Advanced Components Ltd. (England). Price: $2,850.—General Measurement Co., Inc., Newton Highlands, Mass.

Circle No. 321 on reply card

PRIMARY ELEMENTS & TRANSDUCERS

SPRING SUSPENDED

The C70-2407 linear accelerometer combines a novel spring suspension with a highly symmetrical construction, allowing hysteresis and null stability characteristics that were previously unavailable. An electromagnetic damper provides precise dampening

The diversity of applications for Anelex High Speed Printers has been limited only by man's ability to devise new uses for data processing systems . . . For more than twelve years, the most exacting requirements have been met with standard models from the complete line of Anelex Printers or with ingenious adaptations by Anelex Engineers.

ANELEX

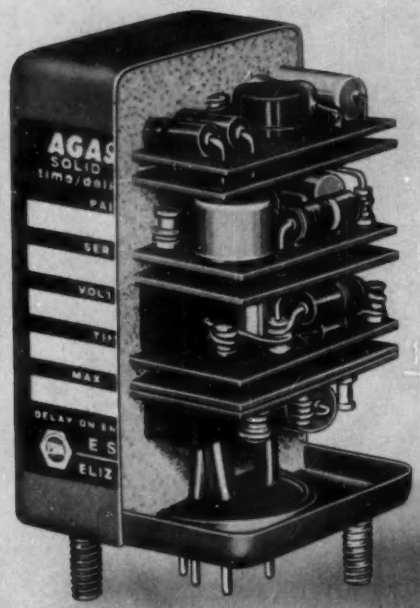
Further information available upon request

ANELEX CORPORATION

154 Causeway Street, Boston 14, Massachusetts

CIRCLE 133 ON READER SERVICE CARD 133

NEW! Solid State time/delay/relays



...with traditional **AGASTAT®** reliability!

Now available . . . solid state time/delay/relays with the accuracy essential for critical missile and computer applications! These new AGASTAT relays are the result of over 25 years' time delay engineering and manufacturing experience . . . specialized experience which has made AGASTAT the standard of reliability throughout industry.

Advanced design combines specially selected semiconductors and other components in a "modular-sandwich" configuration. Result: the standard modules mean flexibility; uniformity; and rapid delivery of "custom" produced prototypes. The solid state AGASTAT is hermetically sealed . . . resistant to vibration and shock. Special circuitry protects against input polarity reversal, provides immunity to voltage transients and continuously modified inputs.

What are your requirements? These solid state relays are only 1-5/16" sq. . . . available in six standard types, with delay on pull-in or drop-out; timing ranges from 0.01 sec. to 10 hours, fixed or adjustable. Operation—18-32 vdc; -55c to 125c; load capacity to 5 amperes. *Write* Dept.S1-310for data sheet. Or ask for a quotation on your special application requirements.

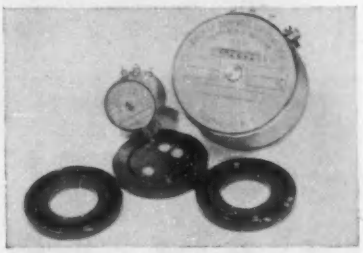
AGASTAT TIMING INSTRUMENTS
ESNA ELASTIC STOP NUT CORPORATION OF AMERICA
ELIZABETH DIVISION • ELIZABETH, NEW JERSEY

IN CANADA: ESNA CANADA, LTD., 12 GOWER ST., TORONTO 16, ONTARIO, CANADA

134 CIRCLE 134 ON READER SERVICE CARD

calibration with temperature stability to within 0.22 percent per deg F. Pickoff is by a variable reluctance transducer. The nonpendulous suspension makes for a minimum of cross-axis sensitivity and negligible angular acceleration sensitivity.—Kearfott Div., General Precision, Inc., Little Falls, N. J.

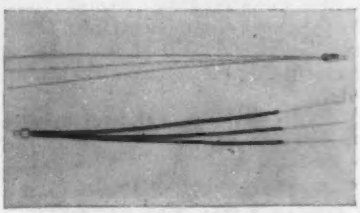
Circle No. 322 on reply card



PLASTIC POTS

The new Fairite line of conductive plastic potentiometers is available in a complete range of sizes from $\frac{7}{8}$ to 5 in. in diam. All units use a continuous bulk track of conductive, high impact, heat resistive plastic molded with an insulating base of the same material. The track provides infinite resolution (to within less than 0.005 deg). Electrical resistance range is 2-50 kilohms ±10 percent with a standard linearity of 0.5 percent. Power rating is 2 watts at 20 deg C with a 3-400 ppm negative temperature coefficient.—Fairchild Controls Corp., Hicksville, N. Y.

Circle No. 323 on reply card



SCREW-IN SENSORS

Surface or subsurface temperature measurement of units whose structural integrity cannot be violated can be made using these small screw-in sensors. Attachment is made by simply drilling and tapping a hole and screwing in the sensor. Tungsten or platinum wound element is contained within a housing that is a standard $\frac{1}{4}$-in. long screw. Screw sizes are available from 2-56 to $\frac{1}{4}$-20. Accuracy is guaranteed to be within 0.1 percent

DU PONT

WIRE AND CABLE ROUND TABLE

You have asked...

Q: What is the straight story on the flammability of polyethylene?

A: Polyethylene is rated as a "slow-burning" material, like rubber and many other materials. Its performance in flame tests depends on the construction. For instance, #6 AWG copper line wire with 2/64" of ALATHON 5, BK22 polyethylene resin passes the horizontal flame test. If you need a truly "self-extinguishing" insulation which will pass the U/L vertical flame test, use Du Pont RULAN flame-retardant plastic (based on polyethylene).

Q: What is the best nylon and best polyethylene for outdoor service? How long will they last?

A: The best outdoor nylon is ZYTEL 37X nylon resin. It contains well-dispersed carbon black, and a good heat stabilizer. We do not know yet what its outdoor life will be, but it has stood up over 17,000 hours in the Weather-O-Meter (unfiltered arc) without failure.

ALATHON 1000 BK-30 is Du Pont's best polyethylene resin for outdoor service. It should be good for well over 20 years (possibly over 40).

Q: I have had trouble with thermoplastic jackets splitting and jamming conduits during pulling. Do you know a good lubricant?

A: Maybe you're using the wrong thermoplastic. We are having great success with jackets of ZYTEL 37X. This product is extremely hard and slick, exceptionally tough, easy to pull. 37X looks good for direct burial cable, too, where you have especially tough plowing conditions.

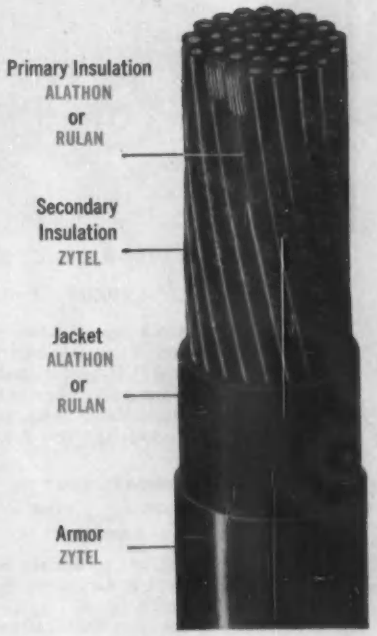
Du Pont does not manufacture wire and cable, but supplies thermoplastic resins for insulation and jacketing.

CONTROL ENGINEERS:

Save 20-35% installation space with Du Pont plastics

Extensive research has shown that the properties of ALATHON polyethylene resins permit a thinner primary insulation with equal or better dielectric performance than other compounds. Result: smaller over-all cable diameter and smaller conduits are practical. Depending on the number and size of conductors, savings of 20% to 35% in thickness over the older constructions are thus possible.

For extreme cases, where the possibility of fire precludes the use of polyethylene, Du Pont recommends the use of RULAN, a flame-retardant plastic, in the same thickness as ALATHON. For secondary insulation, a thin skin of ZYTEL nylon resin imparts exceptional abrasion resistance and higher operating temperature limit. Where mechanical abuse or chemical attack pose a problem, an armor of ZYTEL gives maximum protection.



A typical control cable design that takes advantage of the superior properties of Du Pont plastics is shown at right. For complete information on the use of ALATHON, RULAN and ZYTEL for improving signal and control cable design, send for your copy of Polychemicals Department Booklet WC-3 "Signal and Control Cable Design." Write: Du Pont Company, Rm. CE-10, Polychemicals Dept., Wilmington 98, Delaware. *In Canada:* Du Pont of Canada Limited, P.O. Box 660, Montreal, Quebec.

POLYCHEMICALS DEPARTMENT

DU PONT

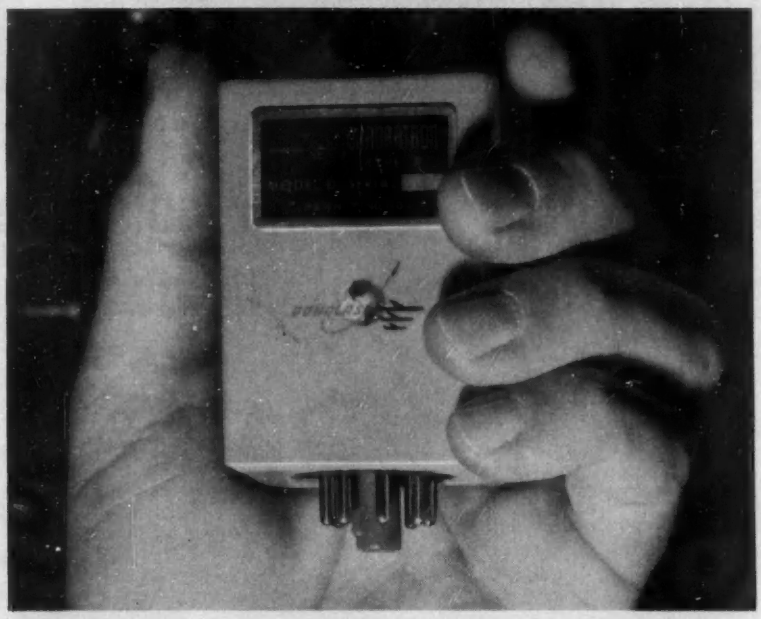
REG. U.S. PAT. OFF.

Better Things for Better Living . . . through Chemistry

ALATHON® POLYETHYLENE RESINS | **RULAN®** FLAME-RETARDANT PLASTICS | **ZYTEL®** NYLON RESINS

CIRCLE 135 ON READER SERVICE CARD 135

Passive QUADRATRON® generates non-linear functions



Three ounce plug-in unit, developed by Douglas, replaces systems many times bigger and costlier

The Quadratron is a unique passive squaring element. It is normally used with standard D.C. operational amplifiers to generate an important class of the most useful non-linear functions. Included are the following:

SQUARE SQUARE ROOT
MULTIPLICATION SINE
COSINE TANGENT

This multi-function versatility is obtained entirely by variations in the external circuitry.

The simple, compact Quadratron has already proved its outstanding reliability in the communications, petroleum, aircraft and missiles, nucleonics, instrument and glass industries.

MODEL SPECIFICATIONS

Type P, Model D Standard
Input signal range, ±100 volts
Squaring Error, 0.4% of full scale
Current from driving source, 2.5 ma.

Type P, Model E Improved Accuracy
Input signal range, ±100 volts
Squaring Error, 0.2% of full scale
Current from driving source, 1.5 ma.

Type P, Model F for Transistorized Amplifiers
Input signal range, ±10 volts
Squaring Error, 0.2% of full scale
Current from driving source, 1.5 ma.

Douglas will supply complete details related to specific applications.

DOUGLAS

MAIL COUPON FOR FULL INFORMATION

Mr. L. M. Spencer, Douglas Aircraft Company, El Segundo, California
Please send me descriptive material relating to the QUADRATRON

NAME _____ TITLE _____

COMPANY _____

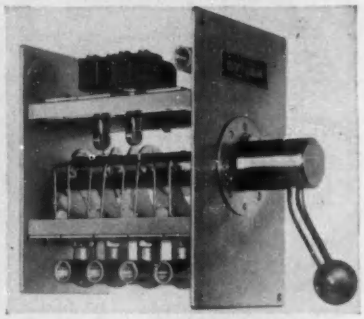
ADDRESS _____

CITY _____ ZONE _____ STATE _____

of full range from −452 to +1,750 deg F. Standard models have resistance range of 20-600 ohms at 32 deg F. Prices range from $125 to 195.— Temptro, Inc., Santa Ana, Calif.

Circle No. 324 on reply card

CONTROLLERS, SWITCHES & RELAYS



CONTROLS SEQUENCES

Ideal for selecting test equipment or for process startup or shutdown sequencing, this new one-knob controller allows 256 combinations for each valve or switch. Each of the six cams is punched with a eight-pronged star hole which fits over the square camshaft. Any combination of valve or switches can be actuated by the cams. Eight stations are shown in the photo above but an arrangement of fewer or more stations can be supplied. Valves are standard two-way 200-psi units with ⅛-in. female pipe thread connections. Switches are spdt, rated at 15 amp at 125, 250, or 480 vac. Price for single switch controller: $89.50.— Dynak Inc., Rochester, N.Y.

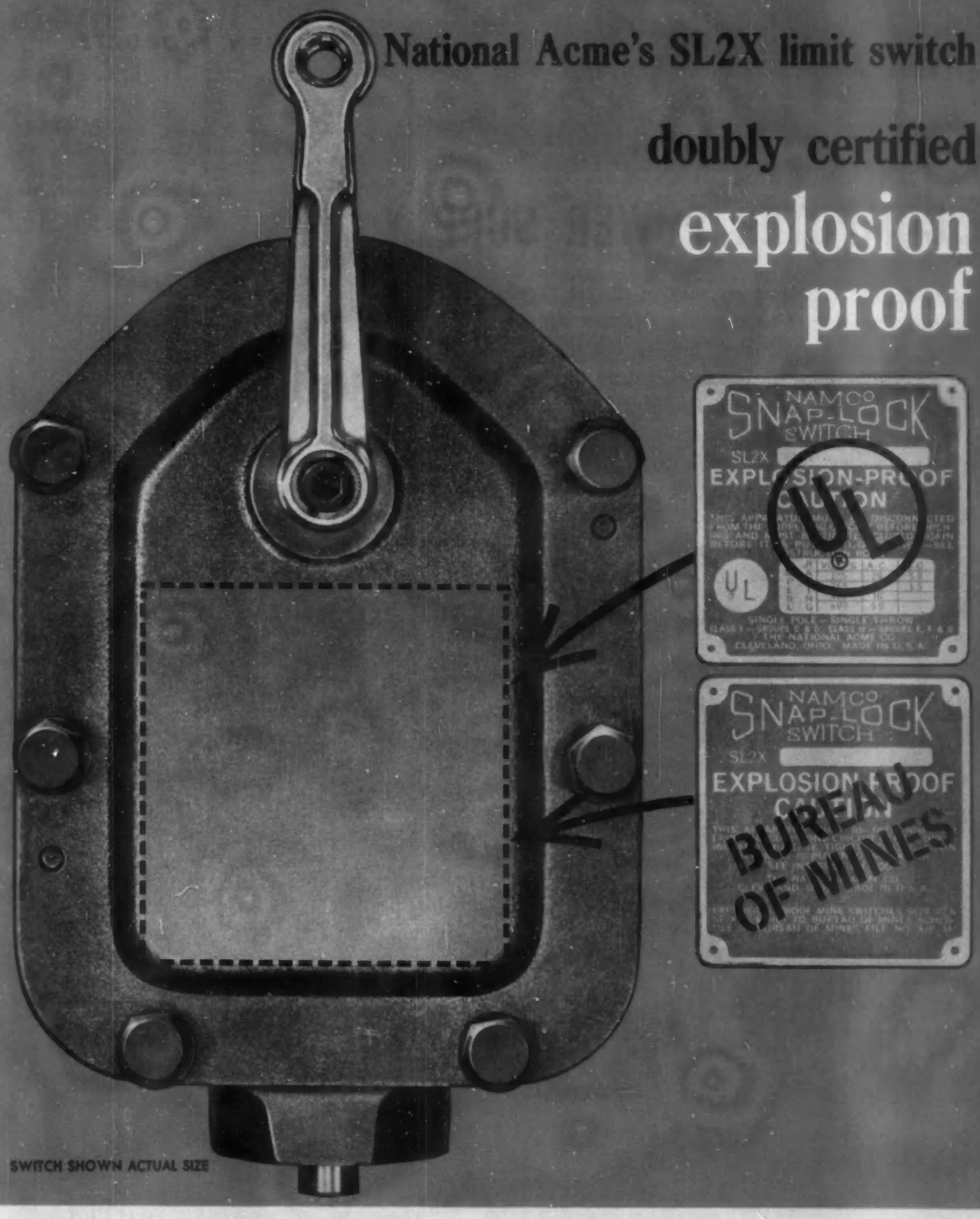
Circle No. 325 on reply card

SCR STARTER

A silicon controlled rectifier is used as the main power switch in this new static motor starter. Unit is designed with modular components and features high reliability because of arc-free operation and the absence of moving parts. Starter can be used with 20-hp motors or with up to 75-hp motors with reduced voltage. Firing and switching circuits are mounted in a standard NEMA-1 wall enclosure. A starter for 220 volts, three phase measures 16 x 14 x 8 in., representing an 86-percent size reduction over satu-

National Acme's SL2X limit switch

doubly certified explosion proof



SWITCH SHOWN ACTUAL SIZE

Specify National Acme's SL2X . . . and eliminate limit switching problems under explosive conditions. Tested and certified "explosion-proof" by both Underwriters' Laboratories and the Bureau of Mines, the SL2X is specifically designed for use in the mining, chemical, process industries . . . anywhere explosions cannot be tolerated. Latest of National Acme's dependable SL2 "Machine Life" Limit Switches, the SL2X also offers . . . a variety of cam arrangements for extreme operating flexibility . . . ample overtravel (67°) and by-pass (90°) . . . light operating pressure (12½ lbs. at 1½" radius). Get all the details on this new standard of limit switching dependability and safety. Call, write or wire.

National Acme

THE NATIONAL ACME COMPANY
165 E. 131st STREET
CLEVELAND 8, OHIO

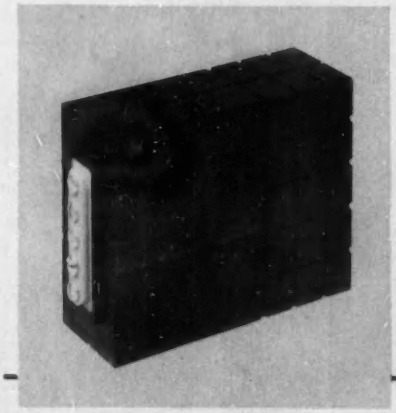
Sales Offices: Newark 2, N. J., Chicago 6, Ill., Detroit 27, Mich.

CIRCLE 137 ON READER SERVICE CARD

"FROZEN-DIODE"
power-bloc

COMPUTER POWER SUPPLY

power-bloc is a proven state-of-the-art regulated dc power supply module. Utilizing the "frozen diode" circuit principle, *power-bloc* achieves precise voltage regulation without transistors, tubes or capacitors. *power-bloc* is available in over 40 standard voltage-current ratings (from 1 volt at 10 amperes to 30 volts at 0.8 amperes).



Highest inherent reliability of any regulated power supply

Fail - safe load protection

Immune to overload

Dimensions of a typical *power-bloc* are 4 by 2 by 5⅜ inches

For additional information on *power-bloc* write to Varo Inc, Electrokinetics Div., East Gutierrez St., Santa Barbara, California.

Varo INC

VARO Inc

2201 Walnut Garland, Texas

Static Power Supplies
Rotary Power Supplies
Controls
Rectifiers
Instruments

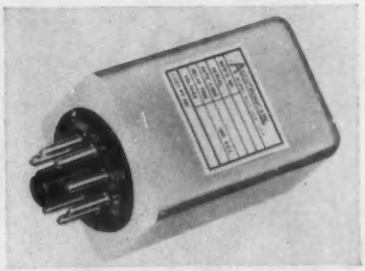
Microcircuitry
Infrared
Optics
Frequency Standards
Magnetics

138 CIRCLE 138 ON READER SERVICE CARD

NEW PRODUCTS

rable core reactor starters.—Westinghouse Electric Corp., General Purpose Control Dept., Buffalo, N. Y.

Circle No. 326 on reply card



LOW COST DELAY RELAYS

Said to be the first line of electronic time delay relays available in a price range suitable for industrial use, these new transistorized devices sell for $29 to $45. The plug-in relays have fixed or adjustable time delays ranging from 100 microsec to 300 sec. Double throw, one, two, or three-pole variations are available with contacts rated at from 1 to 10 amp. Input power is low: 26 vdc, 2 watts max. Recycle time is 50 millisec.—Accutronics, Inc., Beverly Hills, Calif.

Circle No. 327 on reply card

FLOW ALARM

An adjustable alarm is integrally mounted in the weather-proof housing of this new Flow-Eye flow indicator. The unit is made of brass for ¼-in. pipe connections. A plug rises and falls with changes in flow rate, operating a reed type of alarm switch. Switch is adjustable over the flow range of 0.05-10 gpm. Price: $50.—Schutte and Koerting Co., Instrument Div., Cornwells Heights, Pa.

Circle No. 328 on reply card

POWER SUPPLIES

COMPACT SUPPLY

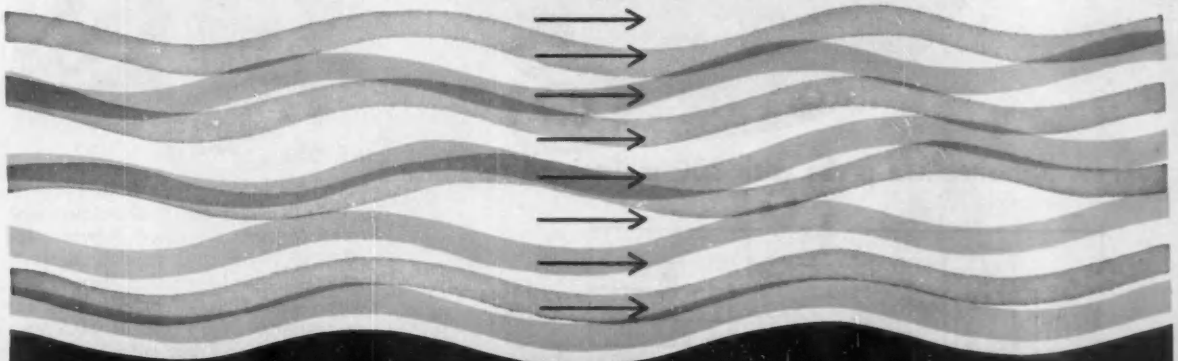
This Model PS110 solid state supply is suitable for test or operation of transistorized circuits, strain gages, etc. Output is 15 vdc, 0-400 ma with overall regulation to within 0.002 percent. Ripple is 50 microvolts. The unit

Honeywell announces the NEW series 1400 low flow control valve

The addition of the new Series 1400 valve body to the Honeywell line of control valves now gives you a choice of actuator-body combinations to match your applications. Now you can choose the exact type and degree of control you need, without pushing a valve beyond its design limits . . . or without paying for more performance than you need.

The compact Series 1400 valve body is available in a full range of materials, ratings and sizes, with screwed or flanged ends. It can be used to regulate small flows in process, pilot plant, research and commercial control systems. Each body size (½", ¾" and 1") has a wide range of reduced ports with Cv's from .025 to 11.0. Two bonnet constructions facilitate mounting of five types of actuators —three pneumatic and two electric.

Each actuator-body combination fits a different range of operating conditions and performance characteristics, but with sufficient overlapping of these ranges to give you a wider selection on the basis of cost. For complete details, write for Bulletin B803-1. MINNEAPOLIS-HONEYWELL, Fort Washington, Pa.



Model 1401 Low Flow Valve with heavy-duty pneumatic actuator for systems requiring high shut-off ratings and accurate valve-positioning.

Model 1403 Low Flow Valve with compact, light weight pneumatic actuator for average industrial and commercial control systems.

Model 1404 Low Flow Valve with reduced port Cv's to .025 and top-mounted positioner integral with pneumatic actuator.

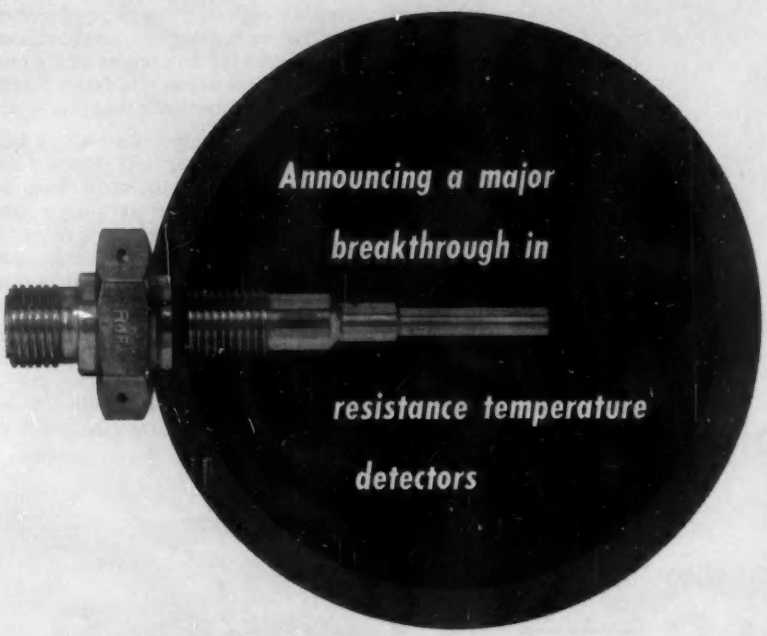
Model 1406 Low Flow Valve with *Modutrol* capacitor-type, electric motor actuator for two-position, floating or proportional control.

Model 1407 Low Flow Valve with heavy-duty *Actionator* electric motor actuator provides more power for higher valve shutoff ratings.

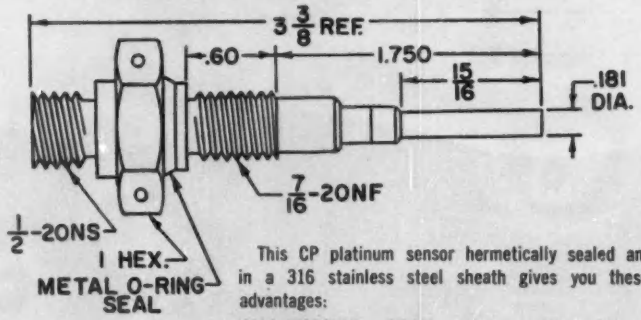
Honeywell

H First in Control

HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.



...new RdF *sheathed* probe with 300 millisecond response



This CP platinum sensor hermetically sealed and protected in a 316 stainless steel sheath gives you these important advantages:

FAST RESPONSE — 63.2% response in 300 milliseconds or less, making it the fastest sealed resistance probe available.

FULL PROTECTION — This new sheathed and sealed probe is compatible with liquid oxygen and ideal for use with corrosive media.

WIDE TEMPERATURE RANGE — Provides precise measurement from M 423°F (liquid hydrogen) to 400°F.

RdF STIKON BN Series

RdF STRAPON RN-100

TYPICAL RESISTANCE DATA RdF TYPE 3255 PROBE

Temperature °F	400	212*	70	32*	-250	-300	-LN
Nominal Resistance OHMS	737	522	438	405	150	100	86

*Standard calibration points

RdF Corporation offers a complete line of standard and miniature probes. Whatever your temperature measurement or control problems, write RdF Corporation for a thorough application engineering review.

Originators of world-famous RdF Stikon® and Strapon resistance thermometers.

RdF Corporation
Hudson, New Hampshire

Formerly Arthur C. Ruge Associates, Inc.

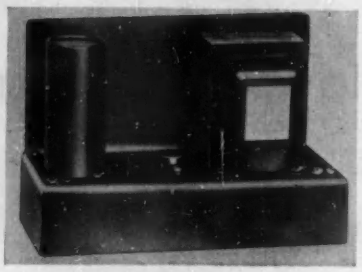
Nashua, N.H., TUxedo 2-5195 TWX NASH 188-U

140 CIRCLE 140 ON READER SERVICE CARD

NEW PRODUCTS

weighs just 5¼ lbs. and measures 2¼ x 8 x 5 in. Under complete short circuit, internal regulating transistor dissipates less than 1 watt. Price: $190.–Dynex Industries, Inc., Syosset, N.Y.

Circle No. 329 on reply card

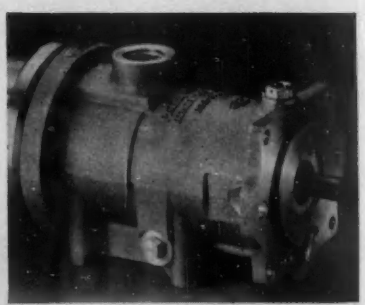


REMOTE SENSOR

Sensing leads, separate from the output leads, are used on these two new transistorized, regulated power supplies to sense, and regulate against, voltage at the load rather than at the output lead. The Model P-56-0.5 has an output of 36-56 volts at 0-0.5 amp and the P-72-0.5 has output of 56-72 volts at 0-0.5 amp. Maximum ripple is 5 mv peak to peak. Static load regulation is to within ±0.05 percent; static line regulation is to within ±0.05 percent for ±10-percent variation. Price for either model: $110. –NJE Corp., Kenilworth, N.J.

Circle No. 330 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS



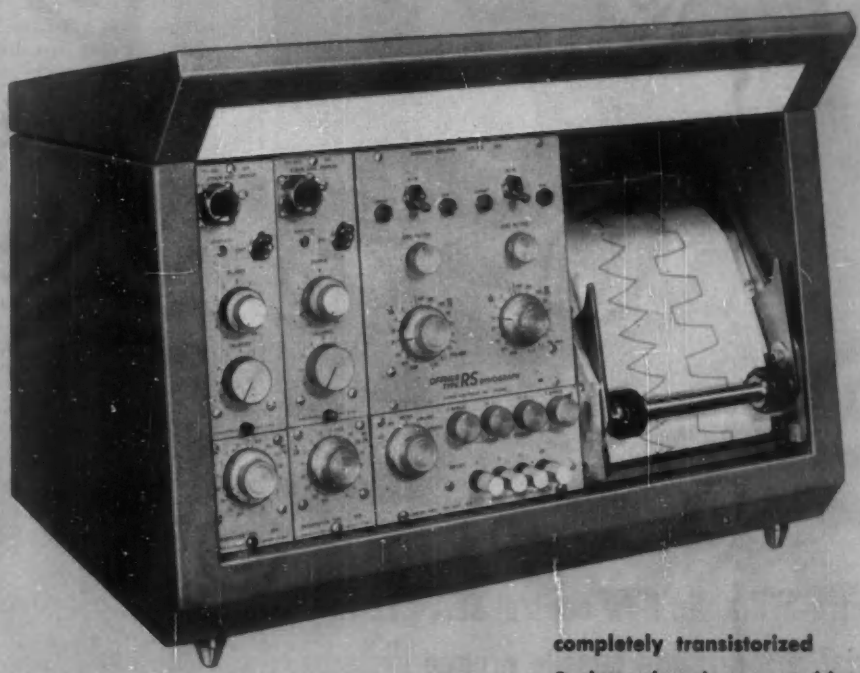
VERSATILE PUMP

Said to be the first pump of its type designed for mass production for the

CIRCLE 141 ON READER SERVICE CARD→

OFFNER

TYPE RS DYNOGRAPH



completely transistorized

2 channel rack or portable mounting

unmatched accuracy and versatility

25 years ago Offner invented the world's first Direct-Writing Oscillograph.

SILVER ANNIVERSARY 1936 1961 25 YEARS OFFNER DIRECT-WRITING OSCILLOGRAPHS

Microvolt sensitivity, unmatched accuracy and compact design are combined with exceptional versatility in this completely new two channel Type RS Dynograph.

All-transistorized, table or rack mounted, conveniently carried for portable use, the Type RS Dynograph provides the same exceptional performance specifications as the Offner Type R Dynograph. Write for complete details.

Sensitivity: With preamplifiers, 10 microvolts per cm to 50 volts per cm.

Warm-up: Instantaneous.

Drift: One microvolt per hour pen drift at maximum sensitivity.

Ambient Temperature Range: —20° to +60° C.

Frequency Response: Within 10% to 150 cps, and 20% to beyond 200 cps.

Recording Media: Rectilinear Heat or Electric, Curvilinear ink or electric, easily converted.

Deflection Time: 2.5 MS with preamplifiers, 1.5 MS without.

Beckman®

OFFNER DIVISION

of Beckman Instruments, Inc.

3900 River Road, Schiller Park, Ill. (suburb of Chicago)

New electro-hydraulic flow control servo valve for industrial, aircraft and missile ground systems

This new line of electro-hydraulic servo valves combines wide versatility with exceptional performance factors for industrial as well as aircraft and missile ground systems.

It features high sensitivity and low leakage. The highly-sensitive spool-type pilot stage valve provides control with input signal power as low as two milliwatts. Application of dither to pilot stage reduces threshold level for use in the most exact systems. Mechanical feedback system balances hydraulic controlling mechanism at position indicated by input signal.

The versatility of this valve permits easy modification for output flows from 1 to 20 gpm at 1000 psi pressure drop. Special models available with flow ratings up to 50 gpm. Rated for system pressures up to 3000 psi, the valve will function with pressures as low as 500 psi with only loss in dynamic response. For complete application information, write or telephone Mr. Lee Wixsom, 750 South Isis Avenue, Inglewood, Calif., Phone — ORchard 1-7589, DDD Code 213.

PERFORMANCE FEATURES OF TYPE 141VN8 SERVO VALVES

Pressure rating: 3000 psi operating, 4500 psi proff, 7500 psi burst
Port Connections: AND10050
Internal leakage at null: 25 cu. in./min. max.
Output flow: shaped or linear
Rated flows: to 20 gpm at 1000 psi drop
Ambient and media temperature limits: —65 F to 275 F and higher

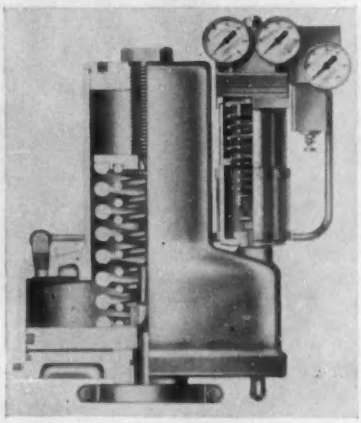
CONSOLIDATED CONTROLS CORPORATION

A Member of The Condec Group

BETHEL, CONNECTICUT
INGLEWOOD, CALIFORNIA

industrial market, this new variable displacement hydraulic pump features control versatility and operation to 2,000-3,000 psi. The WO7 is of the axial piston type with displacement of the seven pistons varied by moving the selector block; the rotating cam is at a fixed angle. Minimum radial loads are made possible by using long piston rods. Displacement control can be by internal pressure compensation, manual handwheel or lever, or servo control. Pump has high mechanical efficiency since there are only two rotating parts: the driveshaft and the cam. Speed range is 450-4,500 rpm. The compact unit weighs 14 lbs. and is 9⅜ in. long by 5¼ in. in diam. A pump for machine tool application would be priced at $100 to $200 in production quantities.—The Weatherhead Co., Cleveland, Ohio.

Circle No. 331 on reply card



PRECISE ACTUATORS

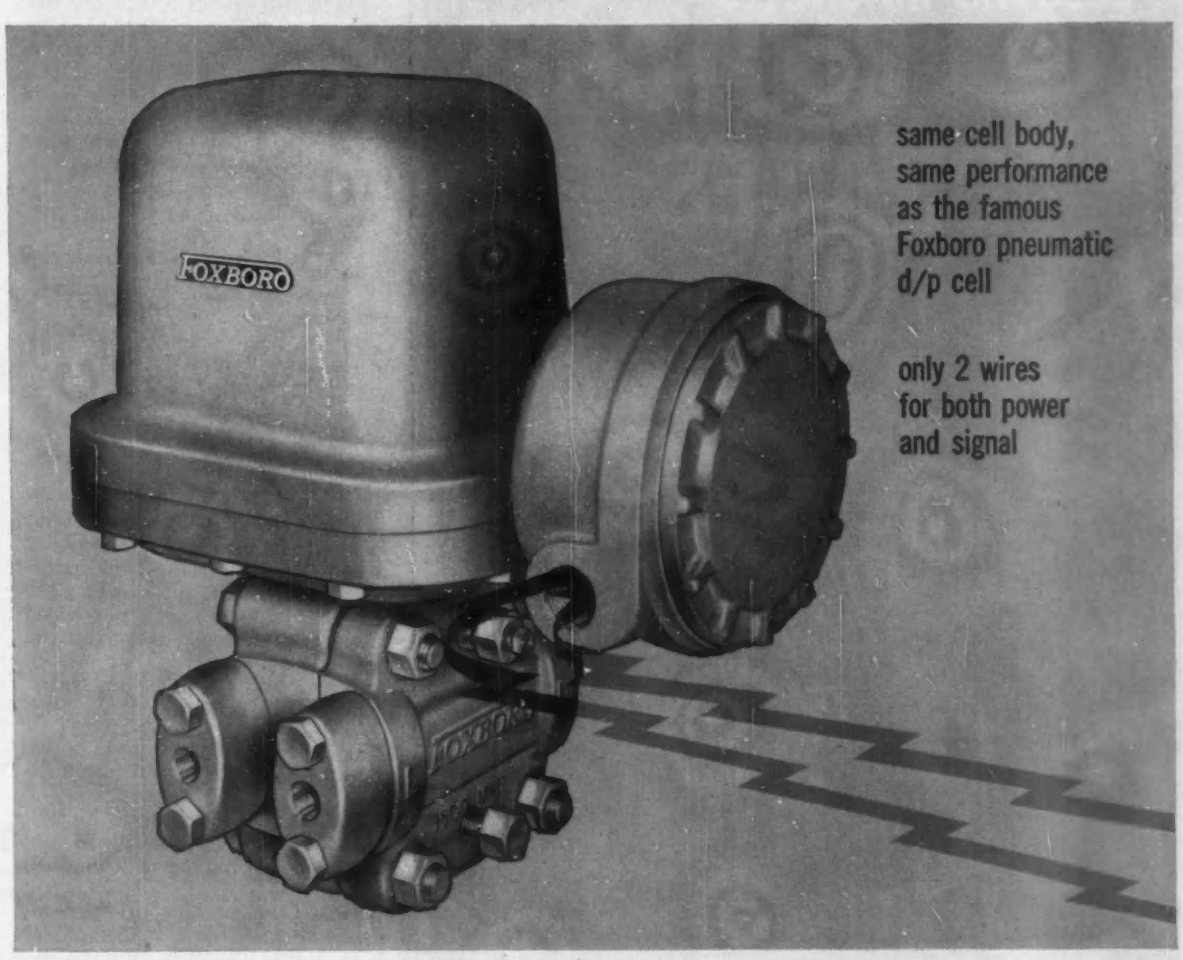
A positioning accuracy to within 0.1 percent of stroke is said to be possible with these new Series P pneumatic positioning actuators. Designed for signal pressures of 3-15 psig, the actuators are furnished with either air-to-open or air-to-closed action and are fully adjustable in the field. Cylinder area ranges from 12.5 to 200 sq. in. with forces up to 18,000 lb.—Security Valve Co., S. Pasadena, Calif.

Circle No. 332 on reply card

MINIATURE VALVE

Said to be one of the smallest available brass miniature three-way solenoid valves, the BM-300 series is credited as being lowest in cost for comparable performance. Standard valves

introducing the Foxboro electronic d/p cell* transmitter



The Foxboro electronic d/p cell transmitter and this Foxboro pneumatic d/p cell transmitter use the identical cell body. Only the top transmitting mechanism has been changed.

Yes, Foxboro has taken its famous pneumatic d/p Cell and added the benefits of electronic transmission. It's the new Foxboro *electronic* d/p Cell transmitter. Look at the results:

- both power and signal travel over the same pair of unshielded wires — no field power supply required
- pressure, flow, and level transmission up to several miles without lag
- true force-balance design for lowest displacement — highest overrange protection
- high level 10-50 ma d-c signal provides powerful rebalancing force
- adjustable ranges from 5" to 850" water with external zero adjustment — working pressures of 1500 and 6000 psi

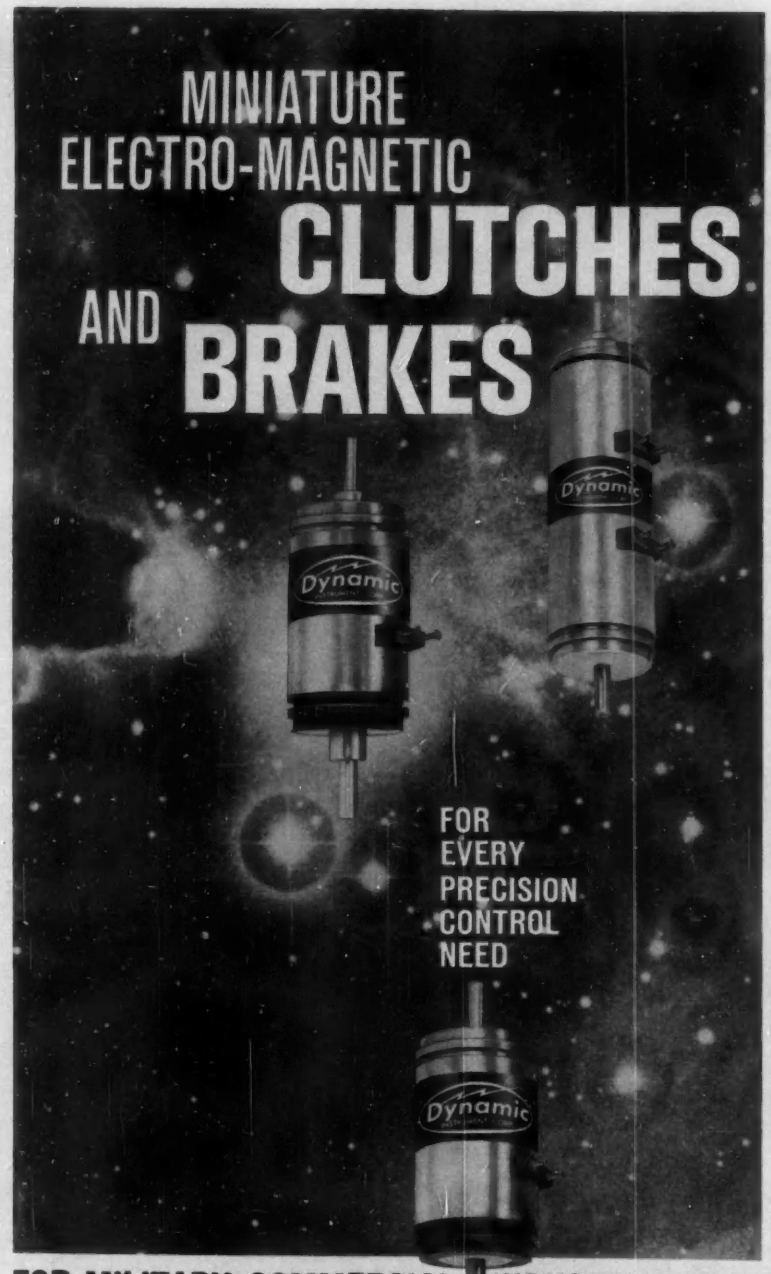
And, of course, you get the same positive overrange protection, the same high sustained accuracy, the same rugged construction that has always been standard with the Foxboro d/p cell transmitter.

If you're thinking "electronic," it will pay you to investigate this important instrument in the Foxboro Electronic Consotrol* family. Get in touch with your Foxboro Field Engineer for complete details, or write for Bulletin 21-10. The Foxboro Company, 8510 Neponset Avenue, Foxboro, Massachusetts.

*Reg. U.S. Pat. Off.

FOXBORO
REG. U. S. PAT. OFF.

CIRCLE 143 ON READER SERVICE CARD 143



FOR MILITARY, COMMERCIAL, INDUSTRIAL USES

Dynamic Instrument makes only clutches and brakes; thus it can offer the **largest standard line,** the most advanced new-design experience, and a highly reliable product . . . proven in the field by major companies to meet all Mil specs* ■ Dynamic's magnetic clutches and brakes are performance-packed precision miniatures that are doing numerous vital jobs such as shaft synchronization, rapid cycling, precise positioning, speed control, and rapid starting/stopping ■ Write for full information.

*Certified test reports on request.

Dynamic INSTRUMENT CORP. *190 Michael Drive, Syosset, L. I., N. Y.*

MANUFACTURERS OF PRECISION INSTRUMENT COMPONENTS THAT HAVE NO COUNTERPART AT ANY PRICE

144 CIRCLE 144 ON READER SERVICE CARD

are available for differential pressures of 0-200 psi; special designs can handle up to 500 psi. NO, NC, directional, and free venting types are included in the series. Weighing only 15 oz, the valve body is 1⅞ in. in diam, ⅞ in. deep, and 3¼ in. high. Operate time is 8-12 millisec. Burst pressure is 6,000 psi. Coils are available for 6-220 vdc, 6-440 vac, and 50-60 cps.—Allied Control Co., Inc., Valve Div., New York, N.Y.

Circle No. 333 on reply card

COMPONENT PARTS

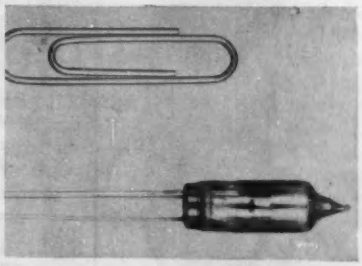
UNIVERSAL TRANSISTOR

A new silicon transistor has been developed that will perform the jobs of up to 40 percent of the 2,000 transistor types now on the market. The 2N2102 combines triple diffusion and planar manufacturing techniques.

Characteristics:

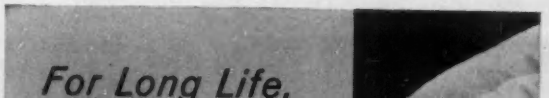
V_{CBO}: 120 volts max
V_{CEO}: 65 volts max
I_C: 1 amp max
Dissipation at case temperature of 25 deg C: 5 watts max
Gain-bandwidth product: 60 Mcps
Switching speed: 30 nanosec max
Price: about $12 in production quantities.
—Radio Corp. of America, Semiconductor & Materials Div., Somerville, N.J.

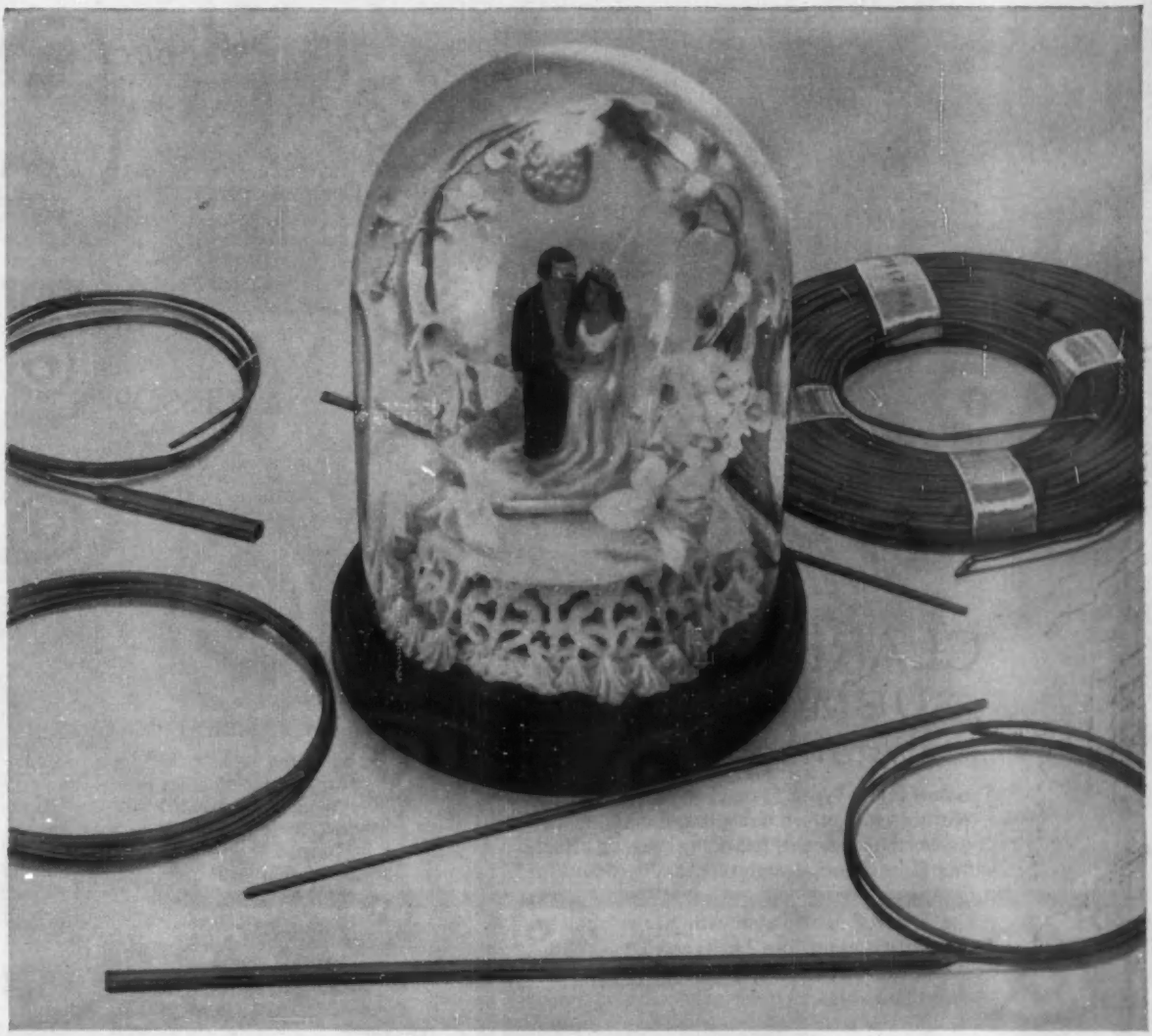
Circle No. 334 on reply card



LOW COST TRIGGER

Said to be priced at a fraction of the cost of comparable units, the Eii-38 cold cathode trigger tube requires no filament power or keep-alive current. The new tube is designed for use in medium speed computing applica-





Married to your present supplier of capillary and restrictor tube? For better—or worse? Next time you need small diameter copper tubing for instrumentation and control systems, think of Kensico. Join our large and growing family of steady customers who know that Kensico has earned its reputation as a Small Tube Specialist the hard way—by superior performance. Highest quality. Accurate flow testing. Exact specifications. Courteous, personalized service. Prompt, dependable delivery.

MARRIED?

New products from Kensico: capped-and-certified restrictor tubing—one-piece capillary tube and bulb assembly. Certified tubing is 100% tested to meet flow specifications. Available in sizes from a minimum of 0.072″ OD by 0.026″ ID to a maximum of 0.172″ OD by 0.115″ ID. Capillary assemblies come in bulb sizes up to ⅜″ OD maximum, by any desired length, with capillary tubing down to a minimum of 0.010″ ID. Call Kensico today. Or write KT-61 for Free Air Flow Engineering Charts.

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COAX

reliable solderless contacts

TYPE LF relay shown (cover removed) is 2-coil design which controls entire latching operation within relay. (Actual size).

CLARE LATCHING SUBMINIATURE crystal can RELAY

The new CLARE Type LF, magnetic latching subminiature relay offers designers simplified circuitry in small space by providing latching effect without transistors. Magnetic latching results in power economy.

The Type LF is available with either 2-coil or 1-coil configuration. The 2-coil relay allows complete control of the latching operation within the relay and provides an extremely compact operating unit. The 1-coil relay is somewhat more sensitive; it is adaptable to existing circuits where outside control is provided. The Type LF provides the same wide range of mounting arrangements and terminals as the CLARE Type F relay.

FOR NON-LATCHING OPERATION

CLARE *Type F* SUBMINIATURE CRYSTAL CAN RELAY

The CLARE Type F relay is extremely fast and more than moderately sensitive. It is built to withstand temperature extremes, heavy shock and extreme vibration. Contacts, rated at 3 amperes, are excellent for low-level circuit operations. Send for Design Manual 203.

For coil and mounting data on CLARE Type LF relay send for CPC-12. Address: C.P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Ltd., 840 Caledonia Road, Toronto 19, Ontario. Cable address: CLARELAY.

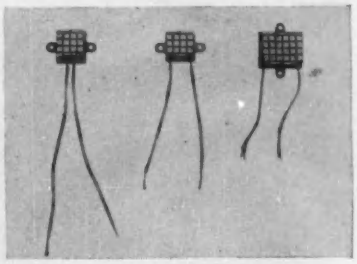
C. P. CLARE & CO.

Relays and related control components

tions, time delays, electronic relays, and counters. Tube body is just 0.9 in. x 0.31 in. in diam. Single units are priced at $1.50.—Electronics Industries Inc., S. Norwalk, Conn.

Circle No. 335 on reply card

ACCESSORIES



LOW CURRENT COOLERS

This new line of thermoelectric cooling/heating modules uses 1/10 the current normally needed to do an equivalent job. Operating current for the Model 629 is 0-3.5 amp on 0-4 vdc. Maximum heat pumping capacity is 8.6 watts, and maximum ΔT is 60 deg C in open air. The Model 615 works on 0-2 vdc and pumps 4.25 watts maximum.—Jepson Electronics, Inc., El Segundo, Calif.

Circle No. 336 on reply card

BALANCES GYROS

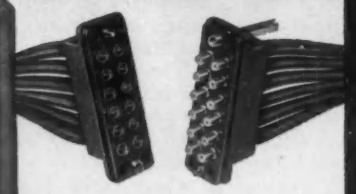
This mass shift compensator is an electrolytic cell with two equal masses of metal at opposite ends of a small glass cylinder. When powered by pure or pulsed dc, molecules of metal plate from one end onto the metal at the other end. Direction of plating, and thus mass shift, can be in either direction, depending on polarity of current. When this device is attached to a gyro, this mass shift can be used to bring the gyro into balance. The compensator is a more attractive balancing solution than using weights or screws, since access to the compensator is by electric signals and is made more easily. The device weighs 3 gm and measures 1 1/8 in. long by 0.25 in. in diam. Power required is less than 1 mw. Shifting capability is $\pm 10^{-4}$ gm-cm sec, 0.030 gm-cm total. Price: $95. Avcon Corp., Scarsdale, N. Y.

Circle No. 337 on reply card

COAX HYFEN® CONTACTS

reliable solderless contacts result in dramatic reduction of installation time

wide application—all with snap-locked removable contacts



Type MB-X

Coax in miniature rectangular configurations.

AQUALOK™

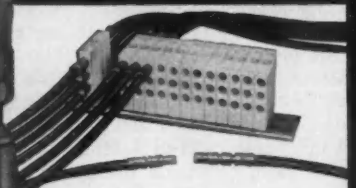
Weather-sealed round connector—either all coax or in combination with single conductors.

Coax Bantam HYFEN

Connectors for standard and miniature coax—either all coax or in combination with single conductors.

Coax Feed-Thru

Miniature and standard connector (above) and splice (below). All plastic shells — lightweight, durable, impact resistant.

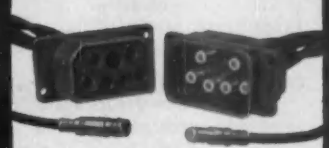


Coax MODULOK®

Modular terminal block with spring-loaded removable contacts.

Type PD-X

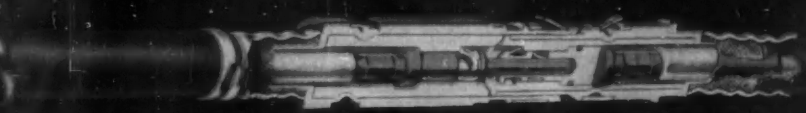
Modular HYFEN inserts for all standard or miniature coax or in combination with inserts for single conductors.



Type ME-X

Rack and panel HYFEN series—features one piece shell, one piece inserts.

Burndy's coax contacts, for both miniature and standard coax cable—feature crimped inner and outer contacts, which provide a more reliable connection, faster and easier. High speed production tooling results in low installed cost—crimps contacts in any circumferential position. Few parts simplify installation. No heat to damage insulation.



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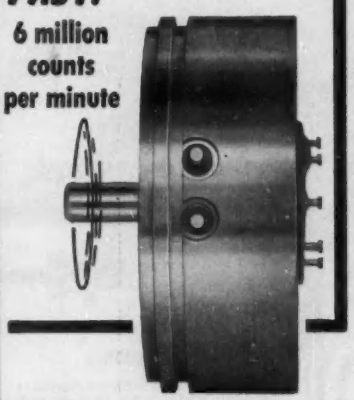
12 BIT PANCAKE INCREMENTAL ENCODER

FAST!
6 million counts per minute



OPTISYN®. . . a unique optical encoder . . . shown ACTUAL SIZE

DIRECTION SENSING
POSITION SENSING
VELOCITY SENSING

HIGH RESOLUTION — 4096 counts per revolution
LARGE SPEED RANGE — 0 to 3000 RPM

OUTSTANDING RELIABILITY — 6 years mean-time-to-failure
RUGGED ENVIRONMENT — meets MIL-E-5272C (15G shock)

AMPLIFIER and FLIP-FLOP OPTIONAL (Model 15EL-2)

APPLICATIONS:

Military **— Special designs now in production as pickoffs for integrating accelerometers and gyro gimbals on Navy and Air Force Bailistic Missile and Submarine Programs.**

Industrial **— Special low-cost designs for machine tools, stereomapping, and digital computers.**

Custom designs available on request.

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DRC DYNAMICS RESEARCH CORPORATION
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Inertial analysis, sub-components and test equipment

Crises in Semiconductors

Overproduction, inventory dumping, immature managements, and "sucker money" from Wall Street are some of the reasons industry spokesmen give for drooping semiconductor prices. The big question for control engineers—the users—is what's happening to quality of transistors and diodes.

Semiconductor prices have dropped so far so fast in the past few months (transistor average off 17.5 percent since January) that makers are seriously worried about the health of the industry. They fear low margin producers flooding the market with low cost products may force other makers to cut quality to meet prices and thus torpedo the reputation for reliability built up by the industry. Users may face the prospect of cheap diodes and transistors at the cost of the reliability they've come to expect.

One symptom of the industry's ailment is found in recent semiconductor company financial statements. Net profit figures are way down. Texas Instruments, Inc., for example, reported its first half 1961 sales rose 3.3 percent but earnings for the period dropped 19.5 percent from the same period last year. General Instrument Corp., which claims to be "doing nicely" increased its first quarter 1961 sales by over 13 percent, but net was up by just a little over 3 percent. And CBS has dissolved its Electronics Div., selling its semiconductor plant and inventories to Raytheon Co. CBS's explanation: "good business decision".

• **Looking for the profits**–Most companies–except some new ones–feel that there are too many producers of semiconductor devices. The glamour of the once booming industry has attracted many small firms into the business. According to industry gossip, many producers padded prices when they introduced a new device (it is this alleged practice that a Federal grand jury is now investigating) and the resultant high profits stimulated investment people to back new companies.

One question industry spokesmen are asking is who started cutting prices. Was it the small producer scared of big inventories? Or was it the big companies who felt they could drive the little firms out of the market? Some spokesmen think it was both.

According to James R. McDade, vice-president in charge of the Transistor Products Div. of Texas Instruments, Inc., "The smaller, newer firms dump their products at lower prices when they get in a tight fix because orders haven't increased as they anticipated."

The big companies, some observers think, watched this dumping and told the newcomers, "We'll show you what price cutting is!"–and then outdid themselves.

• **Inventories build**–McDade also feels that actual demand has just not matched production. The silicon transistor market, for instance, is still 90-95 percent military, he says. In the past it has grown at an annual rate of 30-50 percent, but now it is just slightly above what it was a year ago, although there are signs that it may be picking up. This drooping demand curve and the influx of new faces built inventories throughout the industry and put the pressure on prices.

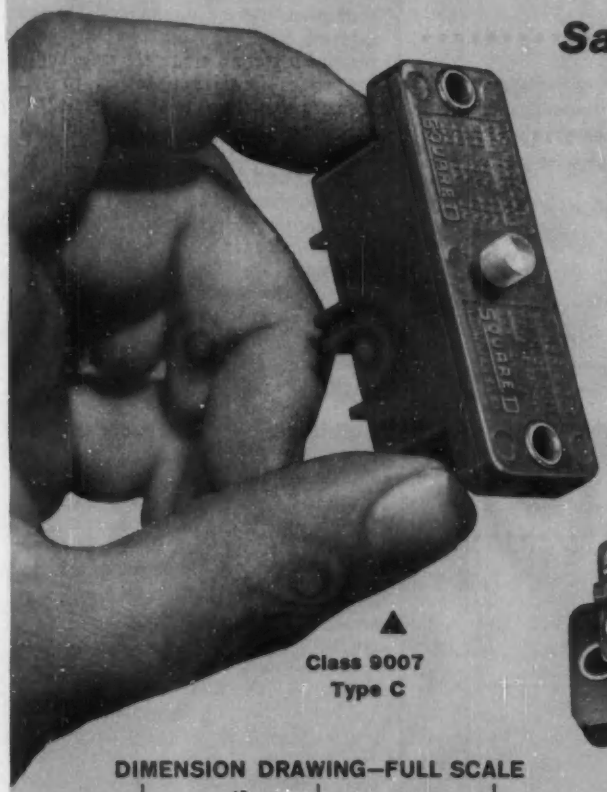
Ted S. Hoffman, vice-president and general manager of Hoffman Semiconductor Div., puts a finger on another aspect of the problem, when he points out that good inventory practices–at least at a full line producer–are tricky with so many different products.

Hoffman also credits business immaturity on the part of many of the new firms for part of the industry's troubles. One bright young engineer frequently is the hub of these little firms. He has a lot of good technical ideas but very little marketing savvy. "Match such fellows against the old pros in the purchasing game," says Hoffman, "and the element of immaturity catches up with you. For instance, they'll quote a price, and the purchasing agent will come back with, 'you're 50-percent high'. So they cut the price.

• **A calculated policy?**–There is some question of whether companies have set out to operate on a loss leader basis, pricing cheap components at a loss to get customers into the house

Now!..

SQUARE D PRECISION *SNAP* SWITCH AVAILABLE WITH 2 POLES!



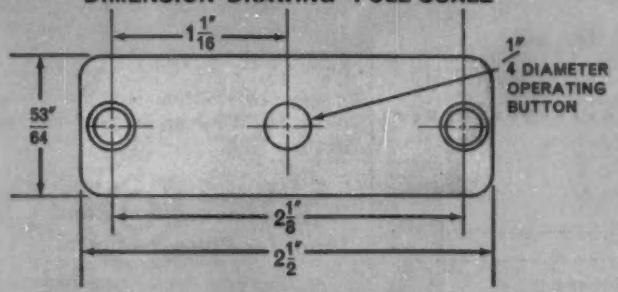
▲
Class 9007
Type C

Same size and mounting as single-pole switch

Here's a precision snap switch which combines 2-pole versatility with high electrical ratings—and takes no more space than a single-pole switch!

The new switch is available either single-throw (2 normally open or 2 normally closed) or double-throw, and like the single-pole switch, it features: double-break contacts—large screw-type terminals—strong melamine case—simplified mounting...a design which assures reliability, precise repeat accuracy and long mechanical life.

DIMENSION DRAWING—FULL SCALE



Write for details. Square D Company, Dept. SA
4041 North Richards Street, Milwaukee 12, Wisconsin

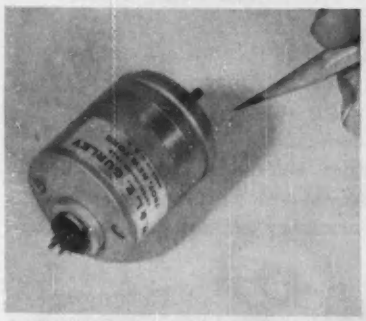
SQUARE D COMPANY

wherever electricity is distributed and controlled

CIRCLE 149 ON READER SERVICE CARD 149

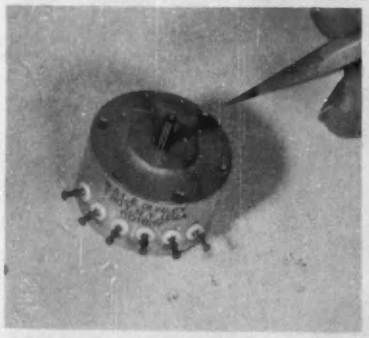
GURLEY Photoelectric PULSE GENERATORS Add...Subtract...Count

Gurley photoelectric pulse generators are shaft-driven, delivering electrical pulses at terminals. Pulse frequency is directly proportional to shaft speed; and pulse amplitude is independent of shaft speed. **Used basically as rate generators or as angle-measuring devices.** All models available with direction-sensing photo cells.



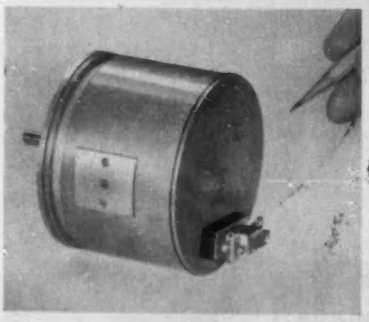
Model 8601

Synchro Mount ..... 1.437" dia.
Length ..... 1.875"
Up to 1024 apertures
Inertia ..... 2.8 Gm-Cm²
Torque ..... less than 0.1 in.-oz.



Model 8602

Housing Diameter ..... 1.375"
Length ..... .844"
Up to 1024 apertures
Inertia ..... 2.8 Gm-Cm²
Torque ..... less than 0.1 in.-oz.



Model 8603

Synchro Mount ..... 3.4" dia.
Length ..... 2.6"
Up to 5000 apertures
Inertia ..... 340 Gm-Cm²
Torque ..... less than 0.1 in.-oz.
Built-in amplifiers available.

Write for information on one or all.

W. & L. E. GURLEY, TROY, N. Y.
537 Fulton Street

WHAT'S NEW

for more profitable lines. According to one Westinghouse Electric Co. spokesman, a 20-cent or even 12-cent diode does not necessarily mean a loss for the seller. "There is no real evidence of any loss leader type of operation. Costs are just plain coming down," he said.

But Stan Niciejewski, sales manager of Sarkes Tarzian, Inc., a small Bloomington, Ind., company asserts that 12-cent price tags on diodes and 18-cent tags on transistors are less than the price of materials alone. He says some companies have been forced to sell regular production items as rejects.

Some of the big firms are redoubling their efforts to sell themselves as quality producers. General Electric Co., for one, sent a letter to its customers over the signatures of H. B. Fancher, general manager of its Semiconductor Products Dept., and C. G. Lloyd, general manager of its Rectifier Components Dept., decrying surplus dumping and pointing out the hazards of quality lapses. The letter set forth GE's program to cut costs and boost reliability.

Moses Shapiro, president of General Instrument Corp., told his company's stockholders at their annual meeting in June, "A proclamation that one will not be undersold by anyone is perhaps appropriate for across-the-street competitors in the department store field but is hardly appropriate in a business in which scientific research, customer engineering and servicing, strength as a mass source, and product reliability should play the crucial roles."

Clearly there's tough going ahead. Some industry sources see the trouble being cleared up soon, with a few mergers and new devices coming out at sustainable high prices. But others see the problem going deeper: "This is not going to happen soon," says Philco's director of semiconductor marketing, Cyrus H. Warshaw, "it may take two or three years."

Westinghouse, Rem Rand Team for Process Control

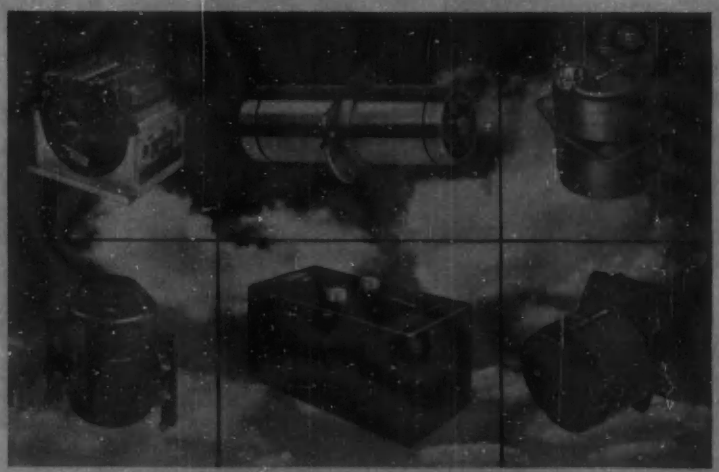
Another joint engineering-marketing venture for teaming computer and process knowhow has brought Westinghouse Electric Co. and Remington Rand Div. of Sperry Rand strongly into the process control field.

The two companies have already begun cooperative development of computer controlled process control loops.—Westinghouse will manage the complete system.

FROM: *Bendix Eclipse-Pioneer*

SUBJECT: *Aerospace gyros, synchros*

SIX LIGHT, RUGGED BENDIX GYRO TYPES MEET BROAD AEROSPACE NEEDS. With the Bendix gyro line, you enjoy a *double* benefit. First, *the line is unusually versatile*—includes models for a wide range of applications, such as radar stabilization systems, aircraft and missile guidance and control systems, bombing and navigational systems, and many others. Second, *high quality of manufacture is consistently combined with such advantages as light weight, proved accuracy, reliability, and ruggedness.*

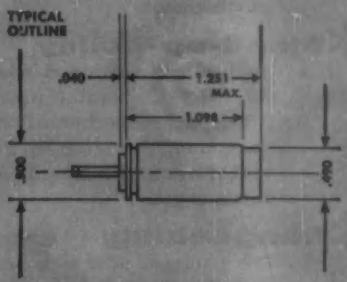


Top: vertical; rate; and directional gyros. Bottom: free-cageable; two-gyro, three-axis (contains both vertical and directional units in a single package); and free-uncageable.

BENDIX GYROS FEATURE: Electrolytic switches for precise erection, long life • 1000-hour operating life • Two-gyro, three-axis control erection rate of 1.3°/min.—with normal erection rate of 2°/min. and fast erection up to 120°/min. for other models.

BENDIX AUTOSYN SYNCHROS FOR MINIATURIZED CIRCUITRY

Where dependability plus size and weight reduction are essential for aerospace applications, these size 5 Autosyn® Synchros can meet your needs exactly. They're available as transmitters, control transformers, and differentials. See typical characteristics below. Further, more comprehensive data available on request.



TYPICAL CHARACTERISTICS

Operating temperature range.....—55°C. to 95°C.
Rotor moment of inertia 0.25 gm cm²
Weight.....0.8 oz.
Accuracy.....±15 minutes

Manufacturers of
GYROS • ROTATING COMPONENTS
RADAR DEVICES • INSTRUMENTATION
PACKAGED COMPONENTS

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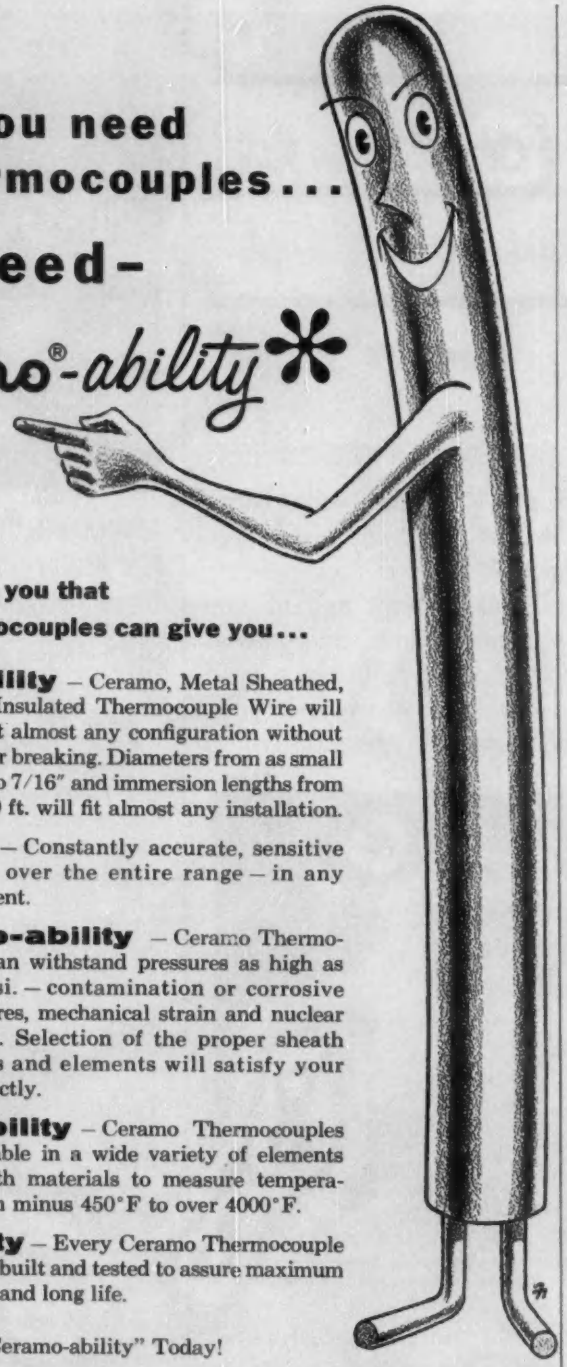
Eclipse-Pioneer Division
TETERBORO, N. J.

THE Bendix CORPORATION

When you need Thermocouples...

You Need–

Ceramo®-ability*



Let us prove to you that Ceramo Thermocouples can give you...

***Adaptability** – Ceramo, Metal Sheathed, Ceramic Insulated Thermocouple Wire will bend to fit almost any configuration without shorting or breaking. Diameters from as small as 1/25" to 7/16" and immersion lengths from 1/2" to 70 ft. will fit almost any installation.

***Stability** – Constantly accurate, sensitive response over the entire range – in any environment.

***Stand-up-ability** – Ceramo Thermocouples can withstand pressures as high as 50,000 psi. – contamination or corrosive atmospheres, mechanical strain and nuclear radiation. Selection of the proper sheath materials and elements will satisfy your needs exactly.

***Rangeability** – Ceramo Thermocouples are available in a wide variety of elements and sheath materials to measure temperatures from minus 450°F to over 4000°F.

***Reliability** – Every Ceramo Thermocouple is quality built and tested to assure maximum efficiency and long life.

Find Out About "Ceramo-ability" Today!

WRITE FOR YOUR 48-PAGE THERMOCOUPLE CATALOG TC-11

–information on all Thermo Electric Thermocouples and accessories.

Thermo Electric

THERMO ELECTRIC Co., Inc., Saddle Brook, New Jersey
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20 YEARS • *Temperature Measuring Systems and Components*

WHAT'S NEW

Schlumberger-Daystrom Tieup to Form Powerful Control Firm

HOUSTON, TEX.—

A new giant in control is being formed out of one of the biggest mergers in the history of the field. A preliminary agreement has been reached for Schlumberger Ltd. to acquire Daystrom, Inc. in a stock exchange deal. Formal director and shareowner approval is still needed.

While few details were available as CtE went to press, it is reported that the many divisioned Daystrom will become the Daystrom Div. of Schlumberger. The surviving company will seek New York Stock Exchange listing. One share of Schlumberger is to be exchanged for each two of Daystrom.

• **Oil well profits**–Schlumberger was formed in France to supply, and still deals mainly in, oilfield services, primarily electronic oil well instrumentation. The business has proved to be highly lucrative to the Houston firm. Sales in 1960 totaled $131 million on which profit after taxes was $17 million. These profits have put the firm in a strong cash position.

Daystrom has realized only skimpy returns on its control efforts: it cleared just $600,000 on $92 million sales last year. Heavy developmental costs have cut deeply into Daystrom's cash reserves. The merger would thus produce a firm with some strong and varied control capabilities and with sufficient funds to back them up.

The Schlumberger family owns about a half of the company's stock, and it is expected that the present president, Pierre Schlumberger, will be president and chief executive officer of the merged company. Thomas Roy Jones, Daystrom chairman, will be vice-chairman, and Daystrom president, John B. Montgomery, will head the Daystrom Div.

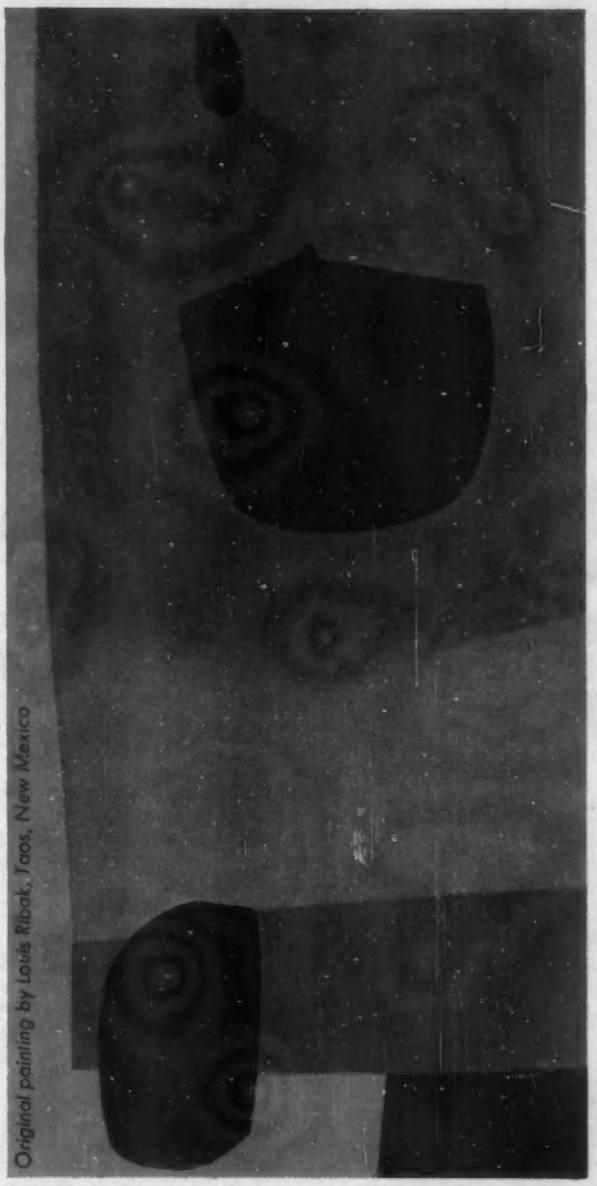
Ford to Buy Philco in $100 Million Deal

Ford Motor Co. has announced plans to acquire Philco Corp. in a mammoth stock exchange transaction. At current share values the price tag would be about $100 million.

Philco holders must approve the move which would make Philco a Ford subsidiary. Ford already has a unit deep in missile, electronics, and control work, its Aeronutronic Div.

Widespread changes are expected in the Philco organization with emphasis on defense and electronics.

Contemporary education, like contemporary art,
continues to find expression in new areas



Original painting by Louis Ribak, Taos, New Mexico

For employees at Los Alamos, a curriculum in Engineering Science of Materials has been added to these in-residence MS degree programs: Nuclear Engineering, Chemistry, Mathematics, Physics, Mechanical and Electrical Engineering.

Qualified applicants are invited to send resumes to:
Director of Personnel, Division 61-84

los alamos
scientific laboratory
OF THE UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO

All qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin. U.S. citizenship required.

NEW... DETAILED DATA ON SERVO MOTORS

Here's information you can use to increase speed and accuracy in high precision control and measuring equipment . . . 4 fact-filled pages on Holtzer Cabot's line of R-24 Servo Motors.

Contains 3 sets of speed-torque, performance curves: (1) For four different stator stackings with 115V on both windings. (2) For four different stackings with 115V on fixed winding and 200V on control winding. (3) For 0.7″ of stator stacking with 115V on fixed winding and 200V, 100, and 50 on control winding. Gives additional data such as starting voltage, stall torque, rotor inertia, acceleration at stall, etc.

The R-24 Line has stator cores of 2.4″ diam., available with stacking lengths of 0.5″, 0.7″, 1.0″ and 1.4″. Models with or without gear trains. Send for your free copy of Bulletin MO-3.7A. Write: Holtzer-Cabot Motor Division, 125 Amory Street, Boston 19, Massachusetts.

HOLTZER NP CABOT
MOTOR DIVISION
National Pneumatic Co., Inc., Boston 19, Mass.

154 CIRCLE 154 ON READER SERVICE CARD

WHAT'S NEW

U.S. Overseas Investment Set to Drop 4 Percent in 1962

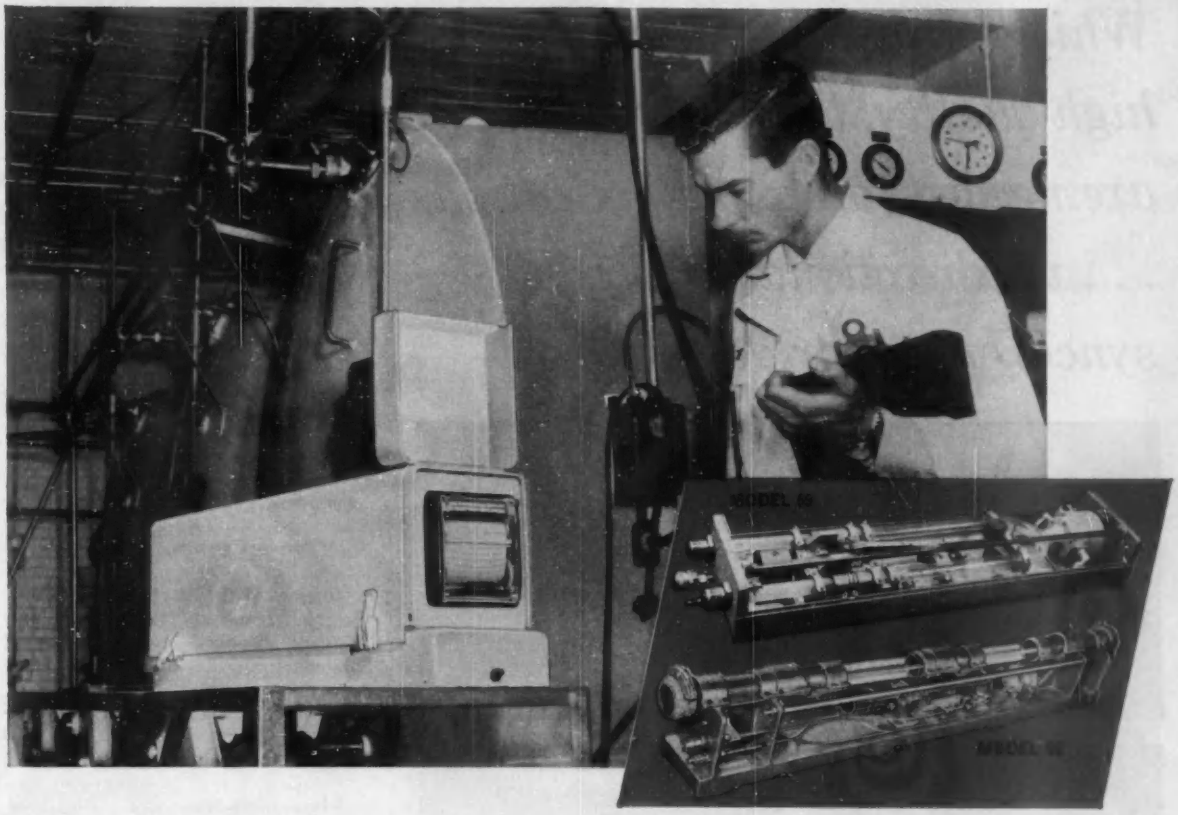
U.S. firms are now making plans for overseas investment in the shakiest international atmosphere since the end of World War II. Troubled by doubts raised by the current crises in East-West relations, the uncertainties following Britain's bid for Common Market membership, and fears over changes in U.S. taxes on overseas income, business leaders are slowing their pace of foreign spending. According to a survey released in September by the Economics Dept. of McGraw-Hill Publishing Co., American industrial companies are setting their sights lower in 1962 after two years of rising spending for overseas plants, property, and equipment.

- **Total investment** is set at $3.3 billion, off 4 percent from this year.
- **Manufacturing companies** plan smaller cuts, now expect to spend $1.65 billion in 1962, a 1-percent drop from the estimated totals for this year.
- **Petroleum companies'** decreases account for most of the drop; they plan to spend $1.64 billion, down 7 percent from this year.
- **Europe** will get nearly one-half of all overseas investment by U.S. business. Manufacturers will devote a third of their expenditures to Common Market countries. In fact, manufacturers will spend 1¼ times their 1960 total in the ECC—1962 spending there should be $539 million.
- **Modernization and replacement** of old facilities will get well over half of manufacturing companies' dollars; petroleum firms hace devoted the major share to increasing capacity.

U.S. Instruments to Enjoy Continued Boom in Japan

A "distinctly favorable . . . outlook for continued profitable participation of U.S. instrument manufacturers in the Japanese market" is how the U.S. Dept. of Commerce puts the outlook for American-made instrumentation in the booming Far East nation. In an eight-page report issued late in the summer, the department's Scientific, Motion Picture, and Photographic Products Div. of the Business and Defense Services Administration tabulates Japanese production of electronic measuring instruments and consumption of all imported instruments and describes the outlook for these goods.

Commerce sees a strong demand in Japan for special analytical instruments in the chemical field and for



Control and/or measure FLUID DENSITY

automatically/directly/continuously

THE HALLIBURTON DENSOMETER is a rugged, low-cost instrument designed to give direct, continuous physical measurement of fluid density, independent of any other fluid property. The Densometer, available in two models, detects any change in density of the fluid passing through it and transmits a pneumatic or electrical signal to key the indicating, recording, or controlling equipment used in conjunction with the device. The versatile Densometer is now in service handling such varied slurries as cement, copper ore, gypsum-water, milk of lime, paper coating, and many others.

TECHNICAL SUMMARY OF OPERATION

Fluid flows through a flexible hollow beam in the Densometer. Changes in weight (density) of the fluid are transmitted through a null-balance system, triggering a pneumatic signal indicating the extent of the change. Response time of the unit is two seconds. These units may be used in fluid systems up to 200°F., 50 psi, ranging from 1.0 to 2.0 Specific Gravity or from 6 to 21 pounds per gallon of fluid.

MODEL 59 DENSOMETER incorporates a ¾" U-tube arrangement and is generally used for sampling operations or mobile installations. The stainless steel U-tube may be used in place of the standard glass tube if desired. A small pump provides a continuous fresh sample at a velocity sufficient to support suspended particles.

MODEL 60 DENSOMETER is the larger unit, incorporating a straight 2" tube, and is usually recommended for systems requiring either large samples or total flow measurement. The center-supported tube permits larger suspended solids to flow through the unit without excessive abrasion. Gravity flow is sufficient with this unit in most applications. Larger diameter models may be furnished to accommodate greater flow specifications.

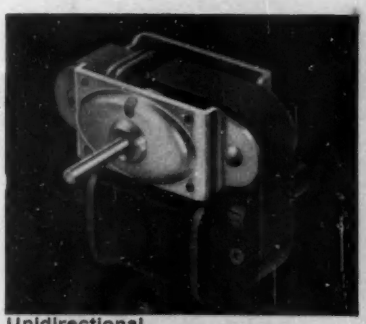
IF YOUR PRODUCT MIX CONTROL IS CRITICAL, investigate the Halliburton Densometer for accuracy within 1% in recording, indicating or controlling fluid densities. See your Halliburton man for all the facts.

SPECIAL PRODUCTS DIVISION

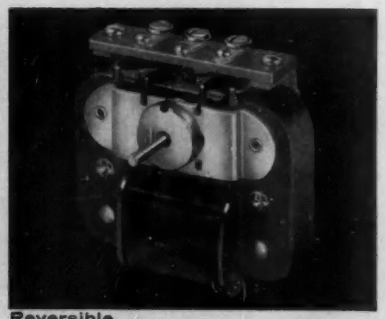
Halliburton
COMPANY • DUNCAN, OKLAHOMA

CIRCLE 155 ON READER SERVICE CARD 155

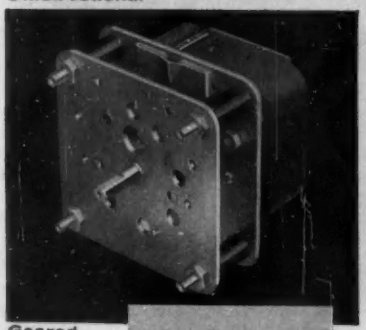
Which of these Barber-Colman high-quality, low-cost motors are needed for your applications . . . unidirectional, reversible, synchronous, or geared?



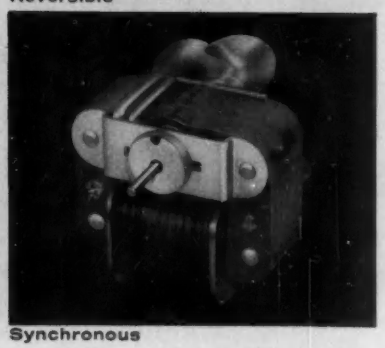
Unidirectional



Reversible



Geared



Synchronous

THE MARK OF QUALITY

BARBER COLMAN

a-c small motors

For longest life and finer service per dollar invested, put Barber-Colman motors into your products. High-quality construction throughout eliminates bothersome, costly maintenance . . . adds to *your* reputation as a builder of quality equipment. Various types and models for use in appliances, vending machines, projection equipment, office machines, toys, servo-mechanisms, remote switching and positioning, recording instruments, and similar applications. And your cost for these precision-made motors is surprisingly low.

LOW COST

HIGH STARTING TORQUE

QUIET OPERATION

LONG-LIFE LUBRICATION

POROUS BRONZE OR BALL BEARINGS

PRECISION-HOBBED GEARS

QUALITY GUARANTEED

WRITE FOR NEW QUICK REFERENCE FILE on the complete line of Barber-Colman a-c small motors: Unidirectional, reversible, synchronous. Up to 1/20 hp. With or without reduction gearing . . . open or enclosed types. Stator and rotor sets also available. Free engineering service.

BARBER-COLMAN COMPANY

Dept. V, 1248 Rock Street, Rockford, Illinois

156 CIRCLE 156 ON READER SERVICE CARD

WHAT'S NEW

high temperature and pressure controls. The largest customers for instruments are the petroleum, oil refining, iron and steel, paper and pulp, and textile machinery making industries.

Copies of the booklet, "Instrumentation in Japan", are available from the Department of Commerce (Washington 25, D. C.) at $0.10.

News of Companies in the Control Field

General Dynamics Corp. has formed a new division—General Dynamics/Telecommunications in Rochester. The unit makes telephone gear for independent companies. GD also has combined its GD/Electronics and GD/Pomona groups.

Racine Hydraulics & Machinery, Inc. of Racine, Wis., has acquired one-third of another Racine firm, Gettys Manufacturing Co. The two-year old company specializes in electronic and electromechanical systems. Gettys will join with Racine to develop complete electrohydraulic systems.

Minneapolis-Honeywell Regulator Co. and **British Aircraft Corp.** have formed BAC-Honeywell Inertial Guidance-Europe to build guidance systems for aircraft and missiles in Europe. The organization will be based in Paris.

Kollmorgen Corp. of Northampton, Mass. has made Instrument Development Laboratories, Inc. a wholly owned subsidiary following acquisition of the Attleboro, Mass., company.

Ampex Corp. has sold its majority interest in Invar Electronics to Behlman Engineering Co. of Burbank, Calif. Ampex acquired its holdings in Invar as part of its merger with Telemeter Magnetics, Inc.

Infonetics Corp. has been formed in Van Nuys, Calif., to build peripheral equipment for data processing. Tape perforators and digital readouts are the first products.

Minnesota Mining & Manufacturing Co. has reached an agreement with Sumitomo Electric and Nippon Electric of Japan to set up a joint venture firm to make magnetic and adhesive tapes. Although 3M is to own 50 percent of the company, the Japanese government is thought likely to approve the arrangement since the government is easing its foreign investment restrictions.

IMPORTANT MOVES BY KEY PEOPLE

Dr. Langford to Head New Kearfott Research Unit

Kearfott Div., General Precision, Inc., has announced that it will set up a Research Center in West Patterson, N. J., and that Dr. Robert C. Langford will head the new facility. Dr. Langford was formerly director of engineering for Daystrom, Inc.

The new Kearfott center will occupy the major part of a new addition to the company's Systems Div. plant in W. Patterson. Work is to be carried on in present product lines and in fundamental studies in a variety of basic fields.

Dr. Van Atta Rejoins Hughes as Lab Technical Head

Dr. Lester C. Van Atta has been named technical director of Hughes Aircraft Co.'s research laboratories in Malibu, Calif., after a year's leave of absence from the company. He was special assistant for arms control for the director of research and engineering in the office of the Secretary of Defense during the past year.

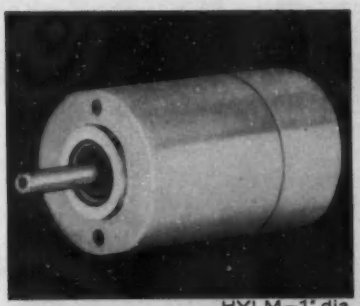
Chalmer Jones Joins Diebold & Associates

Chalmer E. Jones, who resigned as a Daystrom, Inc. vice-president and general manager of Daystrom's Control Systems Div. (CtE, July '61, p. 38), has become a vice-president and director of John Diebold & Associates, Inc., New York based management consulting organization specializing in control systems and data processing. Following his resignation, Jones had formed his own company, Chalmer Jones Co.; Diebold also acquired the assets of this firm.

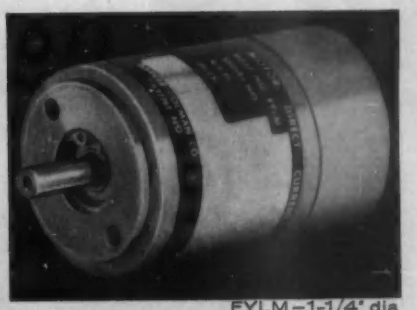
Three Named in Automatic Electric Co. Moves

Dr. John D. Beierle and John E. Fulenwider have taken new posts at Automatic Electric Laboratories,

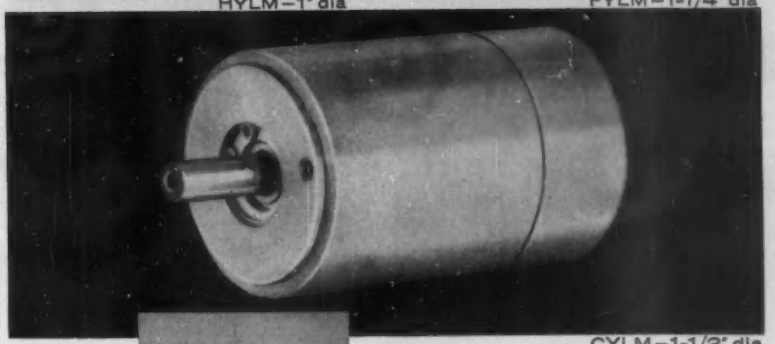
Choose the exact motor you need from the Barber-Colman family of enclosed, permanent magnet, reversible types for industrial and airborne applications



HYLM—1" dia



FYLM—1-1/4" dia



CYLM—1-1/2" dia

THE MARK OF QUALITY

BARBER COLMAN

TOTALLY CLOSED ALL-METAL HOUSING FOR EXTRA STRENGTH AND COMPACT, CLEAN DESIGN

IMPROVED CONSTANT TENSION BRUSH RIGGINGS

ALNICO VI RING MAGNETS CAST IN PLACE FOR MAXIMUM MAGNET AND PHYSICAL STRENGTH

STRAIGHT-THROUGH SHAFTS

MEET MILITARY SPECIFICATIONS

d-c small motors

TYPE HYLM, top left, typical specifications (27 V): Horsepower, intermittent duty — .017. Torque — 1.0 oz-in. Speed — 17,000 rpm. Power input — 23 watts. Length — 1.59". Diameter — 1.00".

TYPE FYLM, top right, typical specifications: Horsepower, intermittent duty — up to .055. Speed — 5,000 to 20,000 rpm. Power input — 2 to 70 watts. Length — 1.77" to 2.40". Diameter — 1.25".

TYPE CYLM, lower photo, typical specifications: Horsepower, intermittent duty, up to 0.1. Speed — 5,000 to 20,000 rpm. Power input — 7 to 155 watts. Length — 2.125" to 3.125". Diameter — 1.50".

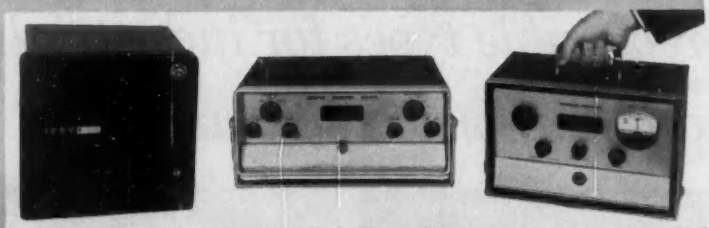
Radio noise filters, gearheads, governors, blowers, other special features also available on above motors.

WRITE FOR LATEST QUICK REFERENCE FILE on the complete line of Barber-Colman d-c and a-c motors, tach generators, blowers, gearheads, ultra-sensitive relays.

BARBER-COLMAN COMPANY

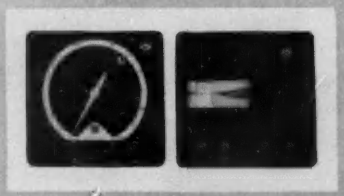
Dept. V, 1848 Rock Street, Rockford, Illinois

NEW BLH-BUILT INSTRUMENTATION INSURES MORE ACCURATE, VERSATILE STRAIN GAGE TRANSDUCER READOUT



The complete line of mv/v instrumentation designed and built entirely by BLH now includes these new indicators for use with any strain gage transducer system.

Type 60 Digital Indicator, shown at left above, is particularly suited to load, pressure and torque systems. It provides system accuracy to ±0.25%—higher accuracies on special order. Designed for panel mounting or bench operation, it is available for fast delivery at a very reasonable cost. With the addition of this instrument, BLH now offers you a full choice of digital, disc or pointer indicators for industrial and laboratory applications.



Type 65 Automatic Calibration Indicator, middle above, is among the most accurate of all BLH instruments. This portable unit automatically reads out in pounds—is used to calibrate a variety of load measurement systems and features automatic null balance, digital readout, plus a built-in check calibrate circuit. Instrument accuracy ±0.05% of interval is standard.

Type 25 Universal Indicator can be used with any BLH load, pressure or torque transducer by simply setting a gage resistance and mv/v output dial on the front of the instrument. Manually null balanced—digital indication—transistorized, lightweight and portable. Instrument accuracy is ±0.1% of full scale. Durable Formica case.

Write for data sheets or contact your nearest BLH sales engineering representative for information and a demonstration.

BALDWIN • LIMA • HAMILTON
Electronics & Instrumentation Division
Waltham 54, Mass.

FIRST in force measurement

SR-4® Strain Gages • Transducers • Temperature Sensors • Systems

158 CIRCLE 158 ON READER SERVICE CARD

WHAT'S NEW

Inc. involving work with electronic telephone exchanges. Dr. Beierle is supervisor of electronic switching systems planning; Fulenwider is supervisor of electronic switching techniques.

Fulenwider replaces Joseph M. Bernstein at the Northlake, Ill., subsidiary of General Telephone & Electronics Corp. Bernstein is now a staff engineer for systems with the company's sales corporation.

Other Important Moves

John J. Connolly has been named a vice-president of Litton Systems, Inc. and general manager of the Data Systems Div. Connolly has been with the Beverly Hills, Calif., company since 1955 and has worked on the company's data systems activities since their start.

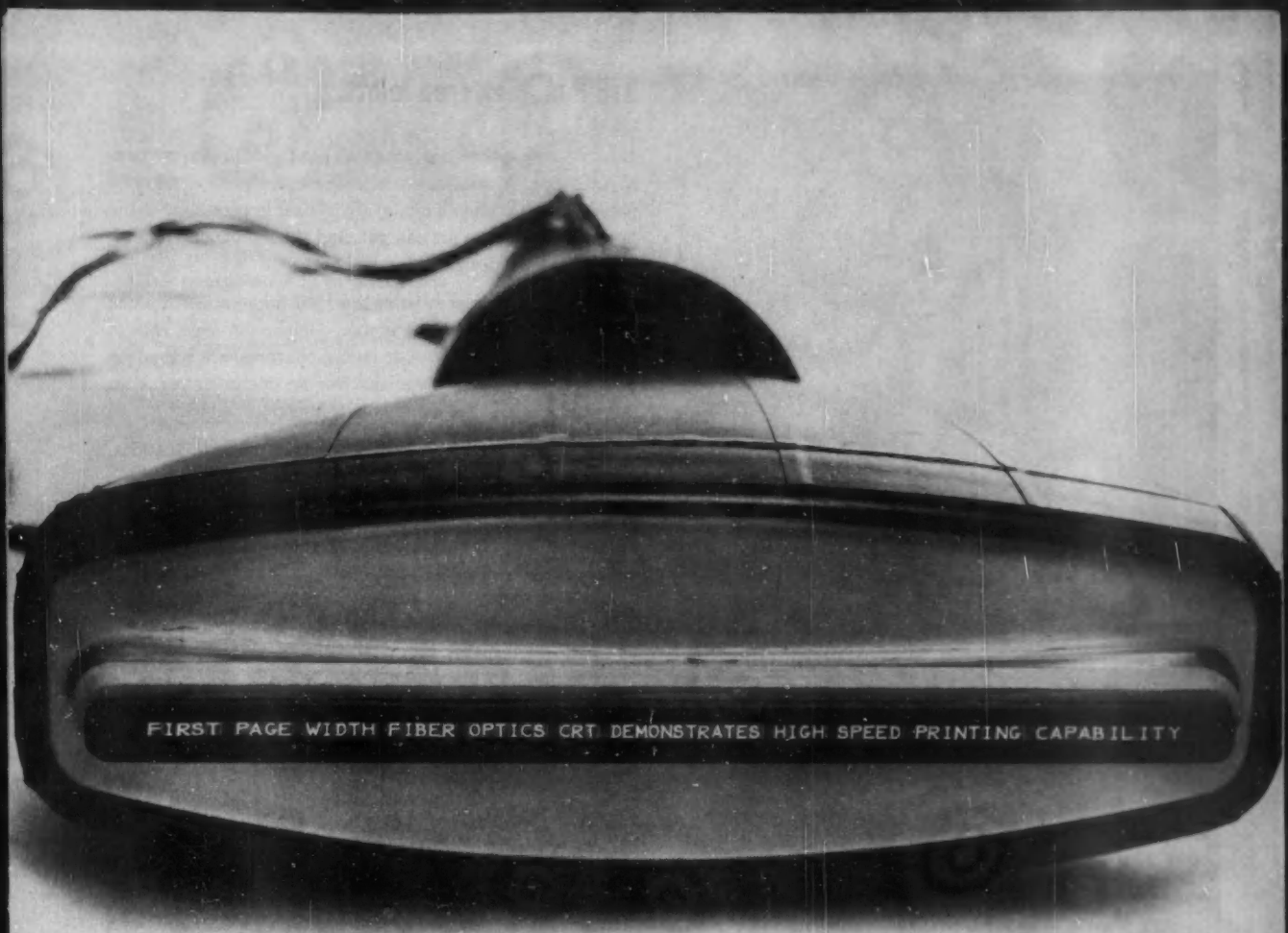
Dr. Lindon E. Saline will head the newly established Specialty Devices Operation (CtE, Sept. '61, p. 230) of General Electric Co.'s Defense Systems Dept. in Syracuse, N. Y. Dr. Saline was manager of DSD's Information Systems Section.

Elmer W. Torok has joined International Rectifier Corp., El Segundo, Calif., as development manager for microcircuitry. Torok is a metallurgist and specialist in molecular engineering. While with Westinghouse Electric Corp. he directed the establishment of a pilot line for production of molecular electronic devices.

Dr. William F. Ballhaus has been appointed executive vice-president of Northrop Corp., and **Frederick Stevens** has become a corporate vice-president and has replaced Dr. Ballhaus as general manager of the Beverly Hills, Calif., company's Nortronics Div.

Robert W. Bowman has become director of product planning for Walter Kidde & Co., Inc. His new post will involve responsibility for new product evaluation and investigation of the future of existing products for the Belleville, N. J., company.

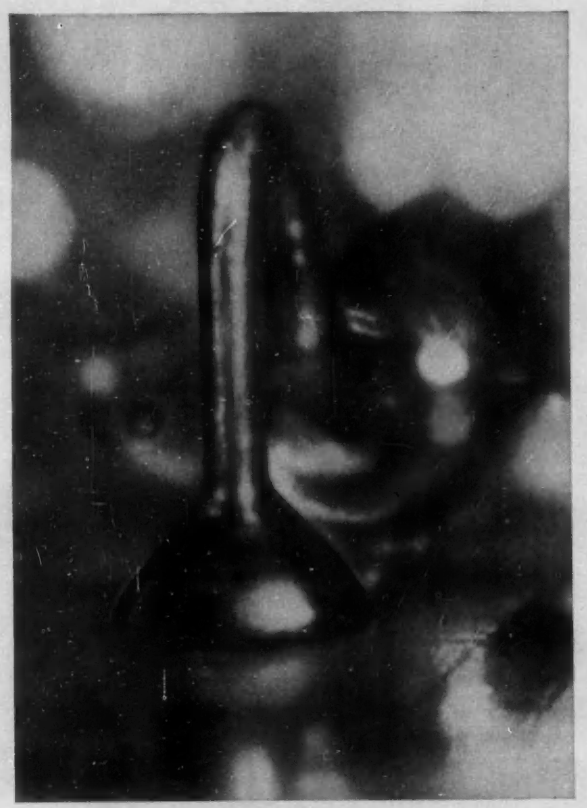
Roy A. Olerud and **William B. Croxville** have been named general managers of the Industrial Electronics and Electronic Tube Divs., respectively, of Allen B. Du Mont Laboratories, Divs. of Fairchild Camera and Instrument Corp. in Clifton, N. J.



You are looking at the first page-width fiber optics cathode ray tube. The unretouched photograph shows the extraordinary brightness and resolution of this General Dynamics/Electronics development which results from combining an 8½ x ½ inch fiber optics bundle with the CHARACTRON® Shaped-Beam Tube. Halation, light scatter, diffusion and complicated optical systems are eliminated. Applications of the tube include high-speed line-at-a-time printing and recording of computer data. For further information about fiber optics or other advanced data processing devices, write General Dynamics/Electronics, Information Technology Division, Department B-65, Post Office Box 2449, San Diego 12, California.

GIIIIIIID

GENERAL DYNAMICS | ELECTRONICS



316 Hand-Soldered Joints.

Dip-soldering techniques just aren't good enough. Navcor transistorized digital systems modules (an elegantly conceived, compatible series of plug-in cards) are as near to perfection as the present state of the art can get. And their production measures up to their design.

Result (from a paper read at the 1960 National Electronics Conference, Chicago): "The motion comparison logic, reversible counter and the digital-to-analog converter are composed of Navcor 300 Series Modules. Over an operating period of eight months, there was only one component failure."

Which is why, in Government and industrial specifications, you so often see the phrase "Navcor, or equal."

Data on modules or consultation on complete special-purpose digital systems on request. Navcor, Valley Forge Industrial Park, Norristown, Pa. GLendale 2-6531.

NAVCOR

Transistorized Digital Systems Modules and Special-Purpose Digital Systems

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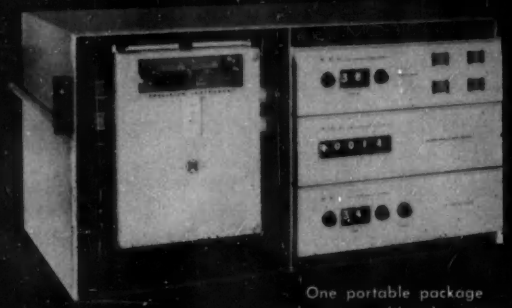
and up to

50% SAVINGS IN COST!

A RELIABLE AND ECONOMICAL WAY TO RECORD

- √ STRAINS
- √ PRESSURES
- √ TEMPERATURES
- √ POSITION INFORMATION



One portable package replaces a multi-rack system

CONDENSED SPECIFICATIONS

Data Channels 48
Input Levels ± 4 millivolts to ± 4 volts
Accuracy (full scale) 0.1%
Sampling Programs Selectable by front panel switch
Sampling Rate Up to 3000 sps
Display Decimal display for individual channel data
Output Format Gapped or gapless for all major computers
Test Identification Run number is inserted on tape at beginning of test for identification
Size.....36" x 20" x 24"
Weight .....175 pounds
Supply Voltage.....115 a-c volts

- **CONNECT YOUR TRANSDUCERS DIRECTLY** to MOBIDAC. No external d-c channel amplifiers required
- **GUARANTEED DIRECT COMPATIBILITY** with all major computers. No tape translation required.

OPTIONS: Increased channel capacity . . . 100 or more, Higher Sampling Speeds, Quick-Look Display, Punched Tape and Card Outputs.

90 DAY DELIVERY For Detailed Specifications and Prices, write Dept. CE

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MOBILE DATA ACQUISITION SYSTEM

S E L SYSTEMS ENGINEERING LABORATORIES, INCORPORATED

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CATALOGS AND BULLETINS

The first two items are examples of especially useful applications literature. Both are available by circling the indicated number on the reader service card, as are the other new literature items.

Strain recording

Detailed information is given in this well illustrated 20-page booklet on the recording of strain gage measurements with the manufacturer's universal strain amplifiers and direct writing oscillographs. Typical strain gage configurations and their applications are detailed and illustrated, and full information is given on temperature compensation and lateral deformation effects. Strain recording circuits for one, two, or four active gages are described. The booklet (numbered Form SR) also tells how to eliminate errors in Wheatstone bridge circuits.—Brush Instruments, Div. of Clevite Corp. **Circle No. 400.**

Silicone rubber

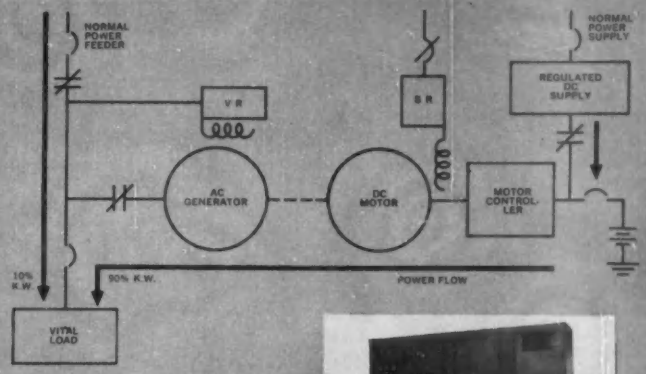
Complete information is given on the properties and uses of silicone rubber in this 56-page illustrated publication. A host of photographs and many clear charts and graphs detail price comparisons, temperature performance, chemical resistance, etc. of this versatile material. Testing procedures and listings of specifications and standards are also given.—Mechanical Rubber Products Co. **Circle No. 401.**

SOLENOID VALVES. Automatic Switch Co. Condensed valve supplement, 16 pp. Contains catalog sheets describing a number of two, three, and four-way solenoid valves developed since the publication of the manufacturer's latest catalog. Photographs, dimension drawings, and two-color flow diagrams complement text that describes valve operation and gives application information. Tables of specifications, dimensions, and prices are included. **Circle No. 402.**

SYNCHRONOUS MOTORS. Bodine Electric Co. Bulletin 1026, 20 pp. Outlines construction and operation of 385 types and models of synchronous motors ranging in size from 1/2,000 to 1/6 hp. In addition to complete text description, listings of available models, speed-torque curves, dimensional drawings, photographs, and wiring diagrams are used to adequately describe the motor line. **Circle No. 403.**

METAL REPLACER. Cadillac Plastic & Chemical Co. Booklet, 24 pp. This publication, prepared by Du Pont, describes the metal-like properties of Delrin acetal resin, a new thermoplastic material that bridges applications of metals and plastics. Curves and tables give strength, dimensional stability, and solvent resistance, among other properties. Photographs and drawing are included of some typical applications, and sections are devoted to the use of Delrin in gears, bearings, and electrical applications. **Circle No. 404.**

CHEMICAL PROCESS SYSTEMS. Fisher & Porter Co. Catalog 310, 8 pp. Describes company's products designed for instrumentation in the chemical process industries and some services such as panel design and user education. Standard



The rating of the AC generator for this Kearfott system is 40 KW, 3 phase, 60 cycle, 460 volts.

CONTINUOUS UNVARYING POWER FOR VITAL INSTRUMENTATION IN CHEMICAL PROCESSING

A TYPICAL APPLICATION OF KEARFOTT UNINTERRUPTED POWER SYSTEMS

In chemical processes where even a split-second interruption of computers and related instruments can cause heavy losses, protection against power failure pays high dividends on a relatively modest investment. Take, for example, the Kearfott system pictured here, which assures surge-free entrance of emergency power in zero time in case the normal input varies or fails.

In normal operation, the DC motor runs continuously on power from the static supply, which also keeps the batteries fully charged at all times. The AC generator operates in parallel with the main power and furnishes about 90% of the vital load requirement.

If the main power fails, the DC motor continues to run, drawing its current from the batteries. Simultaneously, the AC generator assumes 100% of the vital load. When main power is restored, the system automatically reverts to normal operation.

Kearfott systems are available with generator ratings to 150 KVA 60 and 400 cycles, single and polyphase, and provide frequency, voltage and transfer regulation as required by the application.

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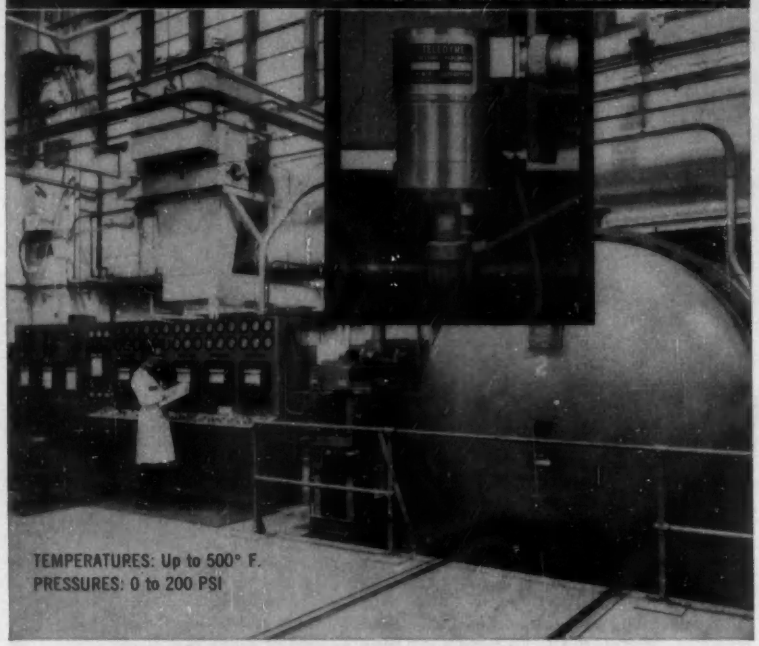

Taber Transducer keeps close tab on autoclave air pressures at Twin Coach

The dependability and accuracy of Taber Bonded Strain Gage Pressure Transducers are pointed up in the manufacture of bonded aircraft assemblies at Twin Coach Co., Buffalo, N. Y.

Assemblies are bonded at temperatures up to 500° F inside a 12′ x 37′ autoclave where atmospheric conditions must be precisely controlled. Mounted externally to permit this high temperature application, a Taber Model 217 Teledyne Pressure Transducer senses autoclave air pressures from 0 to 200 psi, accurately and continuously. *Quality of manufacture is thus insured!*

Among the many performance pluses of Taber Transducers are high frequency response, minimum hysteresis, infinite resolution and low sensitivity to temperature effects, vibration and shock. Models are produced for a wide variety of test, ground support, or airborne applications, with pressure ranges from 0-50 to 0-10,000 psi.

For detailed information on Taber Transducers, mail this coupon attached to your letterhead.

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Send detailed information on Taber Teledyne and Teleflight bonded strain gage pressure transducers.

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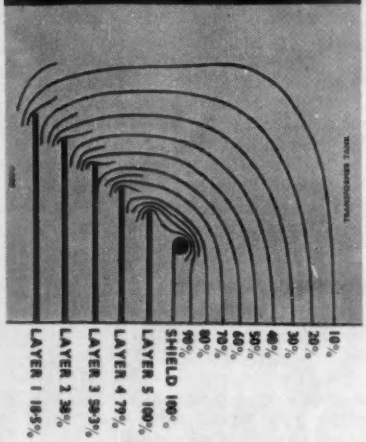

Simplified representation of layer type transformer winding and its resulting field distribution clamps

(shown above is a specimen of work done on this machine)

This novel device can be applied to field problems in many branches of science and engineering; in fact wherever the inverse square law applies. The interesting example above shows lines of electric equipotential in the insulation of a transformer. Observe that the electric stress has been magnified near the windings, because the equipotentials at these points have been plotted every 5% instead of 10% as in most of the field. *Write for data sheet.*

The Field Plot shown above was supplied by the courtesy of the Transformer Development Department of Ferranti Limited, Hollinwood, England.

Send for data sheets.

Servomex Controls Limited
CROWBOROUGH SUSSEX ENGLAND

size and miniature indicators, transmitters, recorders, and controllers and several sensing elements are illustrated and briefly described. **Circle No. 405.**

HEATING CONTROLS. General Controls Co. 1961 condensed catalog, 96 pp. Covers an entire line of heating controls from thermostats through pressure and temperature controls to valves, actuators, and relays. Units are illustrated and complete specifications in convenient tabular form and application information are given. **Circle No. 406.**

DIRECTIONAL CONTROL VALVES. The Oilgear Co. Bulletins 80200-A, 80300-A. First bulletin covers directional control valves with two-way plungers and second, with three and four-way plungers. Valve sizes from ¼ to 3 in. and designed for pressures up to 3,000 psi are included. Units are illustrated and cutaway drawings are used to show construction features. Dimension data, capacities, and specifications are included, as are flow diagrams and ASA symbols and type designations. **Circle No. 407.**

MULTICHANNEL DISPLAY. Philbrick Researches, Inc. Booklet, 12 pp. Operation and applications of a calibrated display system are described in this illustrated publication. A number of reproductions of original traces demonstrate the display system's features and capabilities for analog computing and control system problems. A set of technical data and specifications for a typical installation are included. **Circle No. 408.**

VARIABLE INDUCTORS. Vari-L Co., Inc. Catalog 61, 16 pp. Condenses available information on electrically variable inductors. Describes typical applications of the frequency controlling devices with block and schematic diagrams. Electrical and physical characteristics of the manufacturer's stock units are given in a complete table. Characteristic curves and dimension drawings for the devices are also included. **Circle No. 409.**

COOLING EQUIPMENT. McLean Engineering Laboratories. Catalog, 40 pp. Describes a complete line of packaged blowers, propeller fans, centrifugal blowers, ring fans, and accessories. In addition to photographs of each of the units, complete mechanical and electrical characteristics are given along with performance curves and dimension drawings. A section on basic design information for cooling electronic equipment includes formulas and graphs used in selecting blowers or fans. **Circle No. 410.**

THERMOCOUPLE ASSEMBLIES. Minneapolis-Honeywell Regulator Co., Industrial Div. Catalog G100-1, 40 pp. Complete specifications and updated price schedule are given for a full line of general purpose and special thermocouple assemblies and components. Units are pictured, and available lengths, materials, and connections are listed. A section of selection information gives detailed application guides. Accuracy data and ordering instructions are included. **Circle No. 411.**

MILITARY TRANSFORMERS. General Electric Co. Bulletin GEA-7121, 28

(Continued on page 173)

MINIATURE, HIGH PERFORMANCE MAGNETIC BRAKES AND CLUTCHES

Typical applications involving these Size 11 magnetic clutches, brake clutches, and brakes include service as output controls in mechanical differential computers, as motor brakes, and as speed changers and uncouplers. Kearfott can also provide magnetic clutches, brake clutches and brakes in various other sizes to suit desired applications. Components also available in sizes 8 and 6 diameters.

CHARACTERISTICS

	Magnetic Clutches		Magnetic Brake Clutch	Magnetic Brake
Unit No.	**R5750-001**	**R5750-002**	**R5760-001**	**R5770-001**
Size	11	11	11	11
Power input (Watts)	3	3	3	3
Clutch Torque (In. Oz.)	6 (energized)		4 (energized)	–
Brake Torque (In. Oz.)	–	–	6 (de-energized)	16 (energized)
Inertia (gm cm²)	.82 (energized) .56 (de-energized)		.82 (energized) .56 (de-energized)	.34
Engaging Surfaces	Steel	Brake Material	Steel and Brake Material	Steel
Environmental Performance	Per MIL-E-5272A			
Life (Cycles)*	3,000,000			

*1 Cycle=1 revolution of shaft engaged and 1 revolution of shaft disengaged, at 500 RPM.

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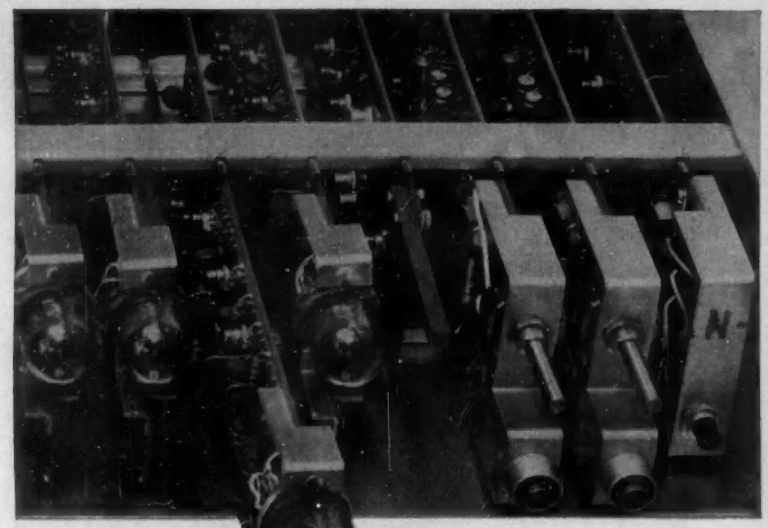


THIS IS WHERE IT COUNTS

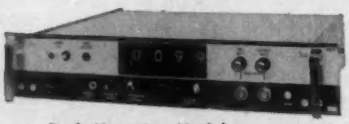
NEW ERIE SOLID STATE 500T BI-DIRECTIONAL CONTROL COUNTER

This is a rugged high-speed control counter with bi-directional capabilities for digital closed loop control. It offers for the first time anti-coincidence circuits for random add/subtract inputs, a digital-to-analog converter and an excess error alarm. The instrument has true modular construction in which individual circuit boards are readily inserted from the front for functional versatility and ease of maintenance. In-line NIXIE readout can be supplied when required.

The unique anti-coincidence circuit used prevents interference between add and subtract pulses arriving simultaneously. This provides absolute accuracy as opposed to conventional anti-coincidence circuits. The analog output is proportional in both magnitude and polarity to the algebraic sum of the add and subtract inputs. The readout indicates the instantaneous algebraic sum.

For example, where the 500T is used for control of motor speeds, the pulses arrive at both the add and subtract inputs at exactly the same rate when the controlled motor is running at the desired speed. Any speed change develops an analog output to a servo system which returns the motor to the proper speed. The same basic process would apply to the mixing of liquids or chemicals.

Applications for the 500T are virtually unlimited since it provides digital control of such parameters as flow, speed, position, and many others. An industrial case is available for applications in rugged environments.



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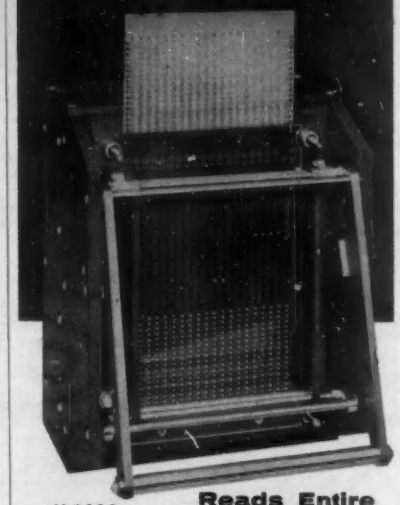

K-1000

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Each hole position has a corresponding closed switch, and each unpunched hole position has a corresponding open switch when the Sensor is actuated. Used for Automatic Test Equipment and other automation devices.

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  Considers sources of electrical noise from transmitters to instruments, and details ways to bring noise down to a minimum level.
- **Stepper Motor Transfer Function**
  Data File develops stepper motor dynamics to permit this discontinuous actuator to be considered as part of a continuous control loop.
- **Single Sheet Classifier**
  System detects pinholes and other imperfections in sheet stock.
- **Mechanical Control Cams**
  Describes spiral contour cam with oscillating follower for measurement, control, and computation.
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404—Metal-like thermoplastic, p. 161
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ADVERTISEMENTS — **Mail Before January 1, 1962**

1	15	29	43	57	71	85	99	113	127	141	155	169	183	197	211	225	239	253	267	281	295
2	16	30	44	58	72	86	100	114	128	142	156	170	184	198	212	226	240	254	268	282	296
3	17	31	45	59	73	87	101	115	129	143	157	171	185	199	213	227	241	255	269	283	297
4	18	32	46	60	74	88	102	116	130	144	158	172	186	200	214	228	242	256	270	284	298
5	19	33	47	61	75	89	103	117	131	145	159	173	187	201	215	229	243	257	271	285	299
6	20	34	48	62	76	90	104	118	132	146	160	174	188	202	216	230	244	258	272	286	300
7	21	35	49	63	77	91	105	119	133	147	161	175	189	203	217	231	245	259	273	287	301
8	22	36	50	64	78	92	106	120	134	148	162	176	190	204	218	232	246	260	274	288	302
9	23	37	51	65	79	93	107	121	135	149	163	177	191	205	219	233	247	261	275	289	303
10	24	38	52	66	80	94	108	122	136	150	164	178	192	206	220	234	248	262	276	290	304
11	25	39	53	67	81	95	109	123	137	151	165	179	193	207	221	235	249	263	277	291	305
12	26	40	54	68	82	96	110	124	138	152	166	180	194	208	222	236	250	264	268	292	306
13	27	41	55	69	83	97	111	125	139	153	167	181	195	209	223	237	251	265	269	293	307
14	28	42	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266	280	294	308

NEW PRODUCTS & BULLETINS — **REPRINTS**

309	320	331	342	353	364	375	386	397	408	419	430	441	452	463		474	485	496	507
310	321	332	343	354	365	376	387	398	409	420	431	442	453	464		475	486	497	508
311	322	333	344	355	366	377	388	399	410	421	432	443	454	465		476	487	498	509
312	323	334	345	356	367	378	389	400	411	422	433	444	455	466		477	488	499	510
313	324	335	346	357	368	379	390	401	412	423	434	445	456	467		478	489	500	511
314	325	336	347	358	369	380	391	402	413	424	435	446	457	468		479	490	501	512
315	326	337	348	359	370	381	392	403	414	425	436	447	458	469		480	491	502	513
316	327	338	349	360	371	382	393	404	415	426	437	448	459	470		481	492	503	514
317	328	339	350	361	372	383	394	405	416	427	438	449	460	471		482	493	504	515
318	329	340	351	362	373	384	395	406	417	428	439	450	461	472		483	494	505	516
319	330	341	352	363	374	385	396	407	418	429	440	451	462	473		484	495	506	517

Name _____ Title _____

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ADVERTISEMENTS — **Mail Before January 1, 1962**

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3	17	31	45	59	73	87	101	115	129	143	157	171	185	199	213	227	241	255	269	283	297
4	18	32	46	60	74	88	102	116	130	144	158	172	186	200	214	228	242	256	270	284	298
5	19	33	47	61	75	89	103	117	131	145	159	173	187	201	215	229	243	257	271	285	299
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7	21	35	49	63	77	91	105	119	133	147	161	175	189	203	217	231	245	259	273	287	301
8	22	36	50	64	78	92	106	120	134	148	162	176	190	204	218	232	246	260	274	288	302
9	23	37	51	65	79	93	107	121	135	149	163	177	191	205	219	233	247	261	275	289	303
10	24	38	52	66	80	94	108	122	136	150	164	178	192	206	220	234	248	262	276	290	304
11	25	39	53	67	81	95	109	123	137	151	165	179	193	207	221	235	249	263	277	291	305
12	26	40	54	68	82	96	110	124	138	152	166	180	194	208	222	236	250	264	268	292	306
13	27	41	55	69	83	97	111	125	139	153	167	181	195	209	223	237	251	265	269	293	307
14	28	42	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266	280	294	308

NEW PRODUCTS & BULLETINS — **REPRINTS**

309	320	331	342	353	364	375	386	397	408	419	430	441	452	463		474	485	496	507
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311	322	333	344	355	366	377	388	399	410	421	432	443	454	465		476	487	498	509
312	323	334	345	356	367	378	389	400	411	422	433	444	455	466		477	488	499	510
313	324	335	346	357	368	379	390	401	412	423	434	445	456	467		478	489	500	511
314	325	336	347	358	369	380	391	402	413	424	435	446	457	468		479	490	501	512
315	326	337	348	359	370	381	392	403	414	425	436	447	458	469		480	491	502	513
316	327	338	349	360	371	382	393	404	415	426	437	448	459	470		481	492	503	514
317	328	339	350	361	372	383	394	405	416	427	438	449	460	471		482	493	504	515
318	329	340	351	362	373	384	395	406	417	428	439	450	461	472		483	494	505	516
319	330	341	352	363	374	385	396	407	418	429	440	451	462	473		484	495	506	517

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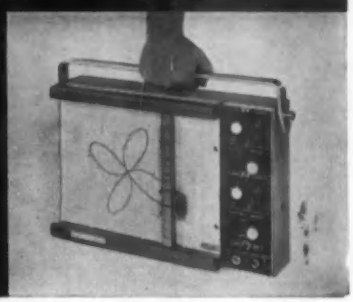

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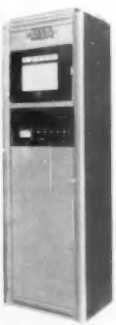

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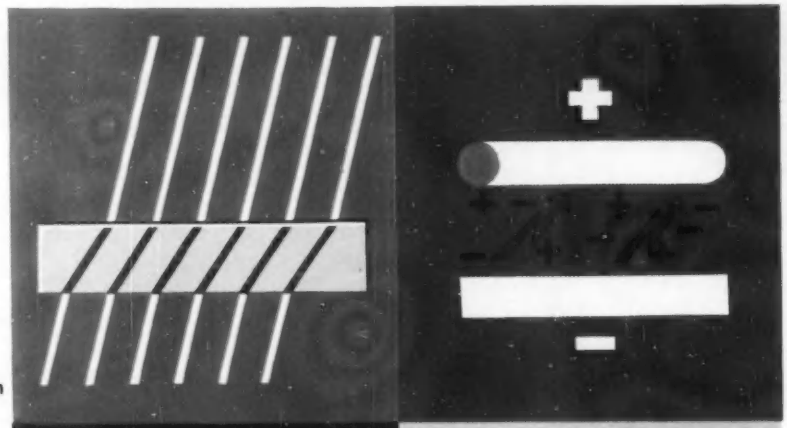
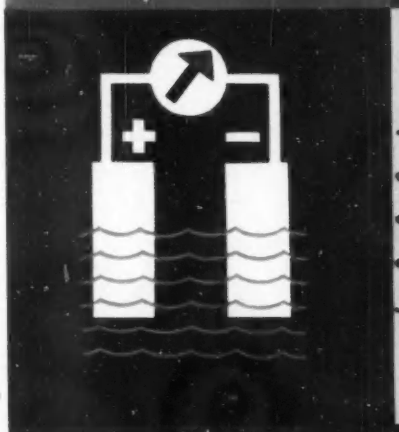
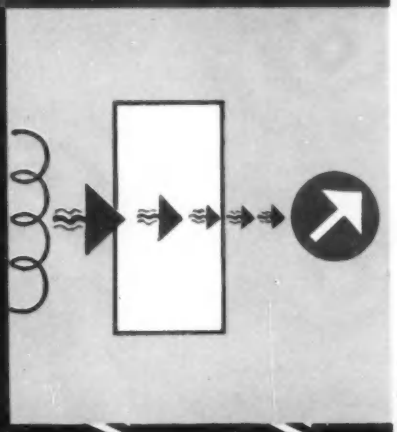


Refraction

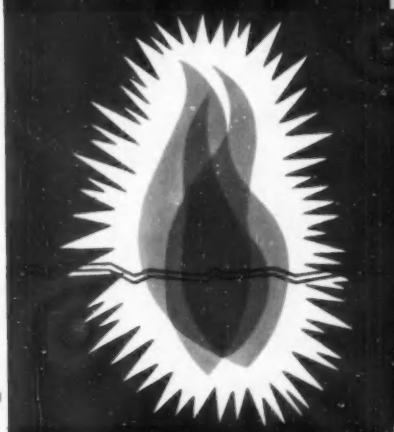
Ionization



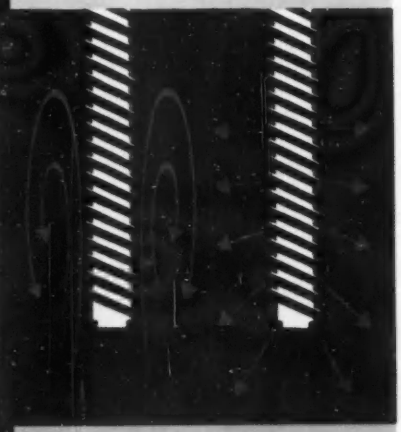
Depolarization



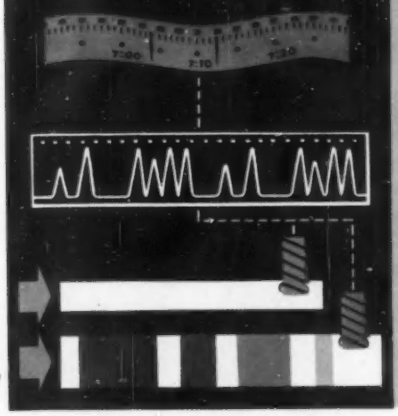
Infrared Analysis



Catalytic Combustion



Thermal Properties



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Catalogs & Bulletins

Continued from page 163

pp. Covers full line of electronic transformers specifically produced for military use. Among the company's stock models are metal cased, hermetically sealed, encapsulated, subminiature, and microminiature transformers. Complete charts give model numbers, ratings, and case dimensions. Outline drawings and wiring diagrams are included. Reliability and military specifications are discussed, and a table gives characteristics of common rectifier circuits. **Circle No. 412.**

PRECISION ADJUSTABLE TIMERS. Technology Instrument Corp., Space Instrumentation Div. Brochure, 4 pp. Describes the micro-adjustable sequence timer, Model 4-23. Clear photographs demonstrate the ease of setting and adjustment. Construction features, accuracy, and switch specifications are described, and dimensional and environmental data are given. **Circle No. 413.**

SHAFT ANGLE ENCODERS. Computer Control Co., Inc., Dychro Dept. Catalog D, 8 pp. Describes a series of linear and sine-cosine optical encoders for converting angular information into binary code. Principle of the encoders' operation and specifications of the units are given in text, line drawings, and photographs. Typical applications are noted, and auxiliary test sets and power supplies are described. **Circle No. 414.**

AIR OPERATORS. Hills-McCanna Co. Bulletin 134-A, 6 pp. Covers eight types of air operators for the manufacturer's diaphragm valves. These valves are recommended for remote and automatic flow control of a full range of corrosive and noncorrosive liquids and gases. Operators listed are for valves from ¼ to 12-in. sizes. Sectional drawings, graphs of air actuator pressures for various line pressures, dimensional data, and ordering instructions are given. **Circle No. 415.**

POWER CYLINDER DATA. Miller Fluid Power Div., Flick-Reedy Corp. Bulletin AJH-104S, 32 pp. Describes manufacturer's complete line of air and hydraulic cyinders, providing all the information needed to select cylinders by size, thrust, bore, stroke, and mounting. Cutaway drawings with accompanying technical descriptions show how the devices are made and how they operate. Color coded tables and charts give information on torque, strength, safety factors, and pressure losses. **Circle No. 416.**

TRANSISTORIZED TELEMETRY SYSTEM. General Electric Co. Bulletin GEA-7163, 8 pp. Starts by describing the nature of telemetry and where telemetry systems should be used. Describes a new transistorized analog system, including complete specifications and typical block diagrams. **Circle No. 417.**

SPEED CONTROL. U. S. Electrical Motors, Inc. Brochure F-1952, 8 pp. Describes 12 typical applications of controlled speed systems. Among those illustrated with three dimensional drawings are five using ac frequency control multimotor systems and single motor systems using variable speed drives and torque motors. **Circle No. 418.**

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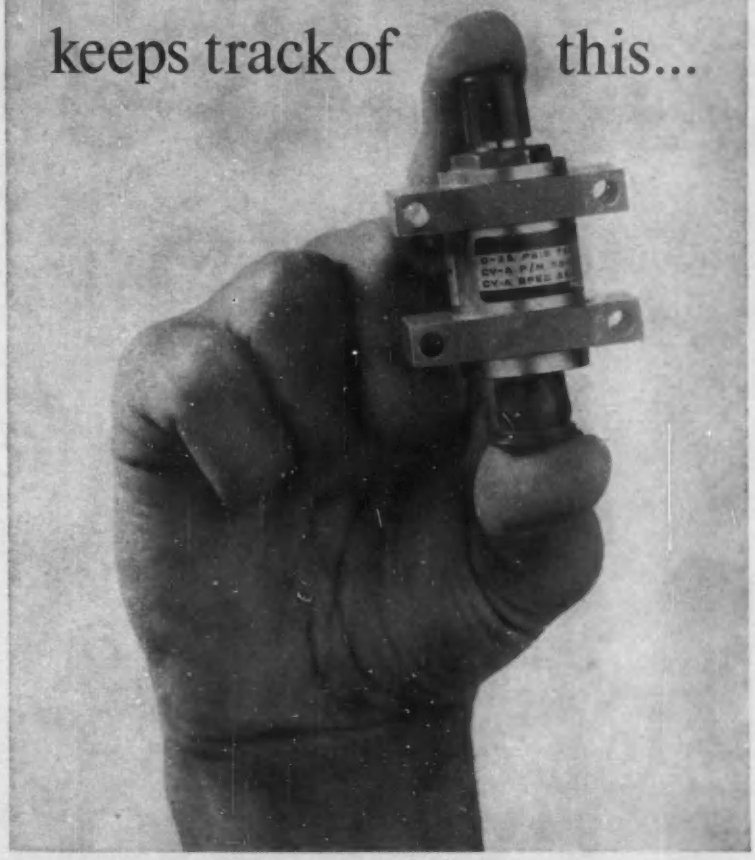

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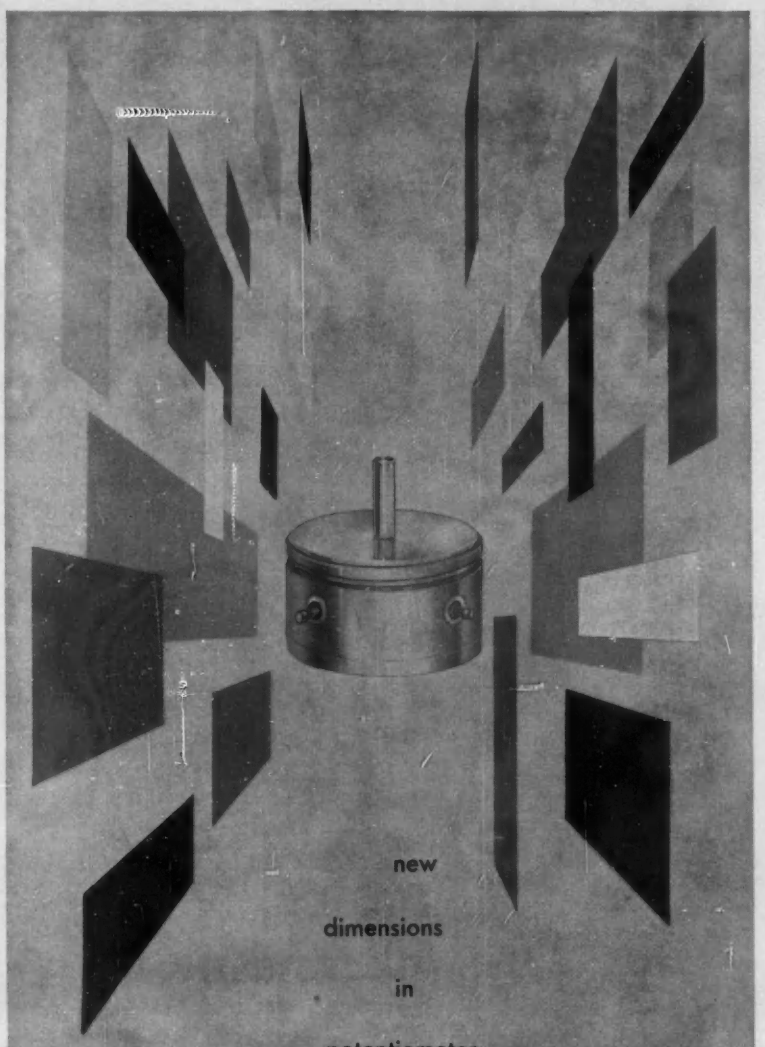

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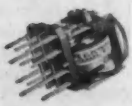

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ABSTRACTS

Measuring haze in plate glass

From "Measuring and Classifying Haze in Plate Glass with an Automatic Hazemeter", by W. W. Preston, ISA Paper No. 10.4, presented at the Joint Automatic Control Conference, Boulder, Colo., June 28-30, 1961.

To quantify a physical characteristic (haze) in a product (auto glass) for both economic and quality improvement, an automatic hazemeter was developed to aid quality control.

Haze consists of minute rouge-filled pits in the polished surface of the glass. Although it is not necessarily detrimental to normal vision, its presence is not desirable. Studies of the light-scattering by the pits revealed that the distinctness of an image is generally affected by the light within the axial area of vision, a 2-deg cone. Over 99 percent of the scattered light is between 0.2 deg and 4 deg from the optical axis.

The instrument devised to measure the haze consists of two main sections —the transmitter, or light source section, and the receiver, or photocell section. The transmitter supplies a near-collimated beam of light to the test sample. The receiver section contains light baffles and a barrier layer PE cell. Test specimens are placed in a 3-in. gap between the transmitter and the receiver. The photocell has a 0.25-in. diam hole drilled completely through the center and is placed to register scattered light within an angle of approximately 4 deg from the optical axis. Unscattered light within a 0.5 deg angle passes through the hole and is sensed by a second photocell whose output is used in a transmission calibration circuit. The scattered light registered by the drilled photocell is amplified and drives a meter calibrated in arbitrary haze units.

The simple manual instrument was extensively tested and its readings correlated with visual and laboratory observations. It then served as a basis for the second phase of development—an automatic hazemeter. This was extensively tested on a conveyor line under actual production conditions.

Finally, using earlier developments, a hazemeter system was made with counters and marking actuators. In this version, four meter relays hooked in parellel at the instrument output are used to signal different degrees of haze, so that quality trend data are logged

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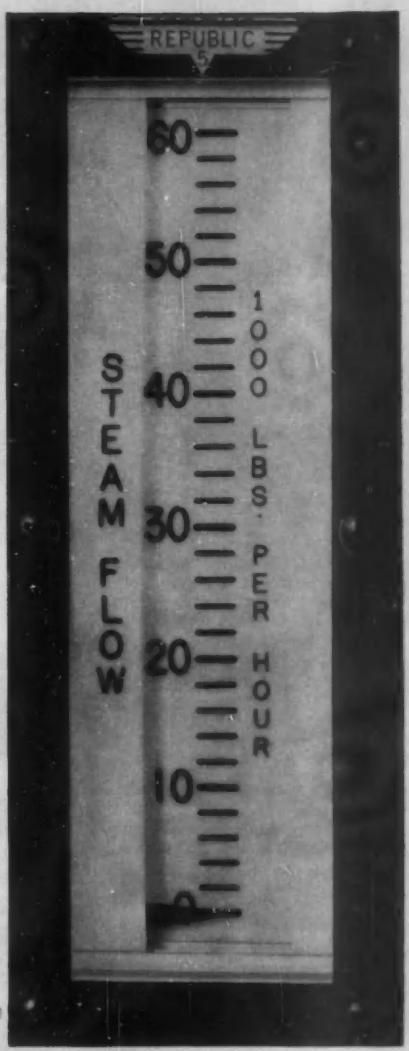

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by the system during automatic inspection of product output.

Computer programs surveyed

From "Third Report on Survey of Electric Utility Applications of Digital Computers", prepared by the Computer Application Subcommittee of the AIEE System Engineering Committee. Available from the AIEE, 33 West 39th Street, New York 18, N. Y. 208 pp., $2.50.

In compiling this survey every utility system with over 75,000 customer meters was asked to submit descriptions of their digital computer programs. Some 325 programs dealing with engineering problems have been arranged in the following categories: Transmission and Distribution Systems, Economics, Structural, Mathematical, Transient Studies, Statistical, Probability, Forecasting, Steam Stations, Hydro Stations, and Computer Language Conversion. The report does *not* include programs for commercial applications, i.e., customer billing, nor does it include many of the all-purpose mathematical subroutines and compiling systems available.

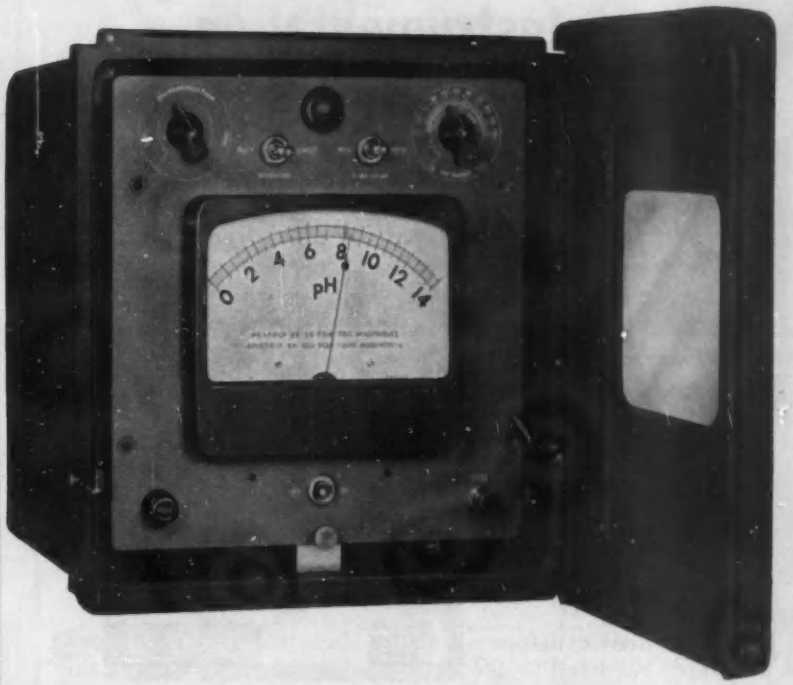
The purpose of the tabulation is to reduce the expensive duplication of time and effort required if each user were to program identical problems independently.

Boiler connection standards

From "Recommended Standard Instrument Connections", prepared by a joint committee of the Recorder-Controller Section of the Scientific Apparatus Makers Association and the American Boiler Manufacturers Association. Available from the Recorder-Controller Section, SAMA, 370 Lexington Ave., New York 17, N.Y., $3.

SAMA and ABMA have made a joint effort to standardize the identification and location of instrument and control connections for power boilers in the 50,000-30,000 lbs of steam per hour range. There are drawings of 44 typical boilers made by the Babcock & Wilcox Co., Combustion Engineering, Inc., Foster Wheeler Corp., and Riley Stoker Co. Each drawing shows the recommended locations of all control equipment and instruments. The introduction contains general nomenclature and recommendations for boiler setting, duct pressure, and temperature element location and installation.

For the best in liquid analysis, see L&N



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A key research and development program is now underway at Atomics International to design long-life, compact, lightweight nuclear reactors that will provide auxiliary power systems for space applications. Many interesting problems exist to challenge electrical engineers who want to relate their present experience to reactor technology in any of the following areas:

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Electrical control system design and/or aircraft or missile flight instrumentation design. Will establish flight instrumentation requirements, block diagrams for flight and test systems, preliminary specifications for each instrument or subsystem.

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NEW BOOKS

Inertial guidance primer

PRINCIPLES OF INERTIAL NAVIGATION, *C. J. Savant, Jr., R. C. Howard, C. B. Solloway, and C. A. Savant, 254 pp., Published by the McGraw-Hill Book Co., Inc., New York.* $9.75.

This book is intended as an introduction to inertial navigation for graduate engineers and ranges over all facets of the problem. The reader will find discussions of varying length and rigor, of accelerometers, gyroscopes, stable platforms, computers, integrators, alignment techniques, mechanization schemes, the relative merit of different coordinate systems, elements of ballistic guidance, gravity, and orbital trajectories.

The authors bring to their task a background of accomplishment in the field, but they have tried to cover too much material in too little space. The book readily betrays its multiple authorship, for its outstanding characteristic is an unevenness in content and development. In too many cases the thoroughness with which a topic is covered bears no relationship to its significance and could mislead a novice. For example, four pages are devoted to double integrating accelerometers which enjoy very limited use in contemporary inertial navigation systems, while the widely used velocity meter is treated in a single page.

In their preface the authors rightly acknowledge that problems of security classification render many of their illustrations obsolete. They would have been better advised to devote more attention to theory than to detailed descriptions of equipment which is no longer representative of the unclassified state of the art.

There can be no excuse for a number of minor but disconcerting errors of fact which can dampen the confidence of the reader in more important matters, e.g., the Schuler pendulum was first described in 1923, not in the nineteenth century; stable platforms *can* be used with vibration isolators; and nitrogen is not chemically inert.

The reader who is familiar with inertial navigation will find little of interest, but for someone seeking an initial insight, this book must suffice for lack of an available alternate. Perhaps a revised and expanded edition in the near future might achieve the author's unfulfilled promise.

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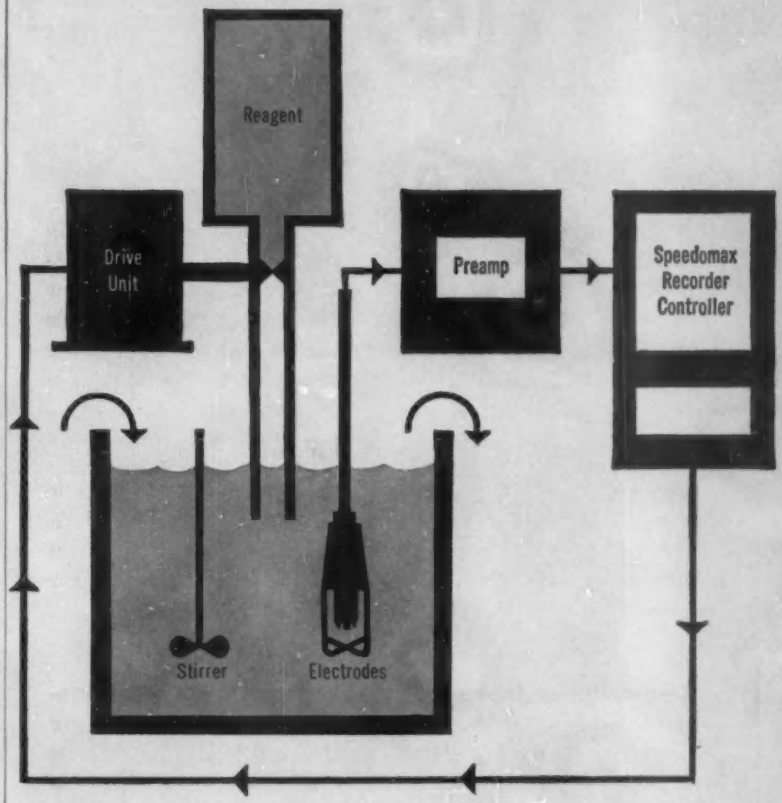

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NEW BOOKS

Guide to pneumatics

COMPRESSED AIR AND GAS HANDBOOK, *Third Edition, 592 pp. Edited and published by the Compressed Air and Gas Institute, Cleveland, Ohio.* $8.

This contains a great deal of valuable information that could, if used properly, help produce improved specifications for compressed air installations. It could be put to good use by engineers designing machinery and recommending types and sizes of compressors, tools, and air motors. It could also be useful to architects.

The big problem is finding the information that fits the majority of cases, for there is too much data relating to special conditions, which clouds the data used in more ordinary situations. A section should have been devoted to a clear, concise explanation of the basic points in setting up a pneumatic system, perhaps in check list form. The more verbose data could be treated as a reference material to be reviewed as necessary.

The small portion on circuitry might as well have been omitted. It is of no aid in component selection or systems design and merely indicates it "can be done." Although cylinders and valves are used by the thousands, they are glossed over rather quickly, and what is said has little real value.

Despite these shortcomings, there is, unquestionably, a wealth of good reference information that can be obtained from this book. It will be useful to those who take the trouble to read it.

E. L. Holbrook
Barker Instrument & Machine Co., Inc.

Mechanisms and machines

THEORY OF MACHINES, *Joseph Edward Shigley, 567 pp. Published by the McGraw-Hill Book Co., Inc., New York.* $11.50.

This is actually two books in one.

Part I, Kinematic Analysis of Motions, deals with the geometry of motions without reference to the forces that cause them. After describing the necessary fundamentals, the author considers real motion-producing situations, including all types of gears, linkages, cams, and analog computing mechanisms.

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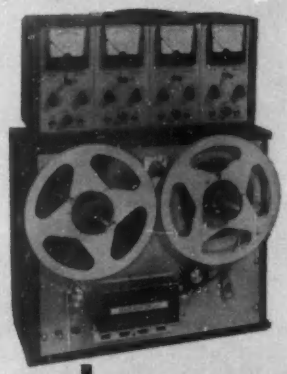

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NEW BOOKS

various machine parts acted on by forces. There is a lengthy chapter on vibration analysis, amply illustrated by practical examples, and a chapter dealing with centrifugal force effects on unbalanced machine parts and techniques of dynamic balancing. The remaining chapters deal with reciprocating engine, cam, and feedback system dynamics. Short appendixes give formulas for finding the position of a four-bar linkage, tables of involute functions, and moments of inertia, along with a description of indicator diagrams.

Each chapter is followed by a set of illustrative problems, and the answers are included. The book is exceptionally well written and is suited for use as a reference or a text for teaching or self study.

Mitchell Salanas
Lawrence Radiation Laboratory

Transistor text

TRANSISTORS: PRINCIPALS, DESIGN, AND APPLICATIONS Wolfgang W. Gartner, 675 pp. *Published by D. Van Nostrand Co., Inc., New York.* $12.50.

Written as a college text and as a tool for the engineer, this book provides the theoretical and practical aspects of transistor circuit and device design, and gives a thorough description of transistor properties and applications.

There is a history of transistor development, and the necessary semiconductor physics and the properties of semiconductors and PN junctions are presented in an analytical and sound fashion. The basic design theory of transistors, first the junction type and then most of the other classes developed to date, is covered next, followed by the methods of characterizing transistors, and the dependence of transistor properties on current, voltage, frequency, and temperature.

The remaining chapters are concerned with circuit applications. There is a comprehensive discussion of biasing, and several categories of amplifiers, classified according to frequency response and power output, are described. The two chapters are devoted to oscillators, and two more to pulse or switching circuits and such nonlinear applications as harmonic generation, detection, modulation, and demodulation.

A. N. DeSautels
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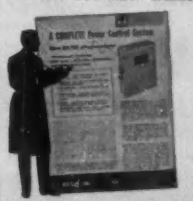

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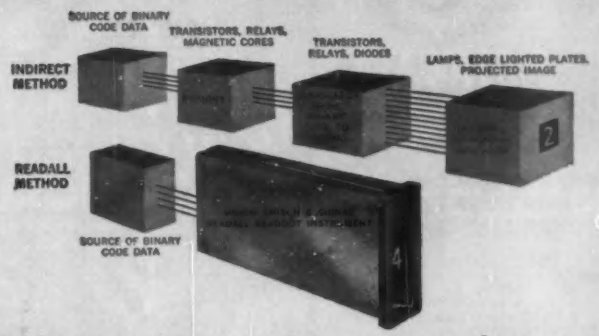

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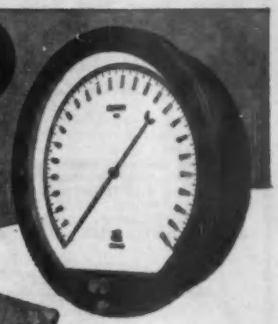

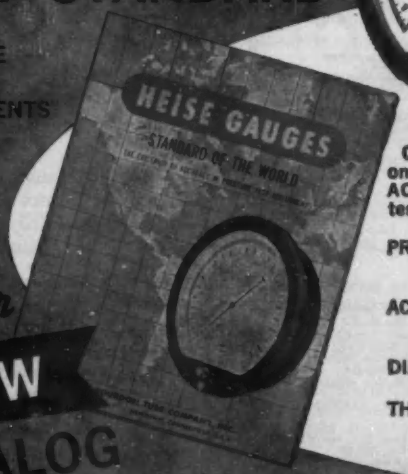

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Institute of Radio Engineers, Canadian Convention, Exhibition Park, Toronto, Canada Oct. 4-6

International Systems Meeting, sponsored by Systems and Procedures Association, Statler-Hilton and Pick-Carter Hotels, Cleveland, Ohio Oct. 8-11

National Electronics Conference, sponsored by IRE, AIEE, EIA, SMPTE, Hotel Sherman, Chicago, Ill. Oct. 9-11

National Conference on Industrial Hydraulics, sponsored by Illinois Institute of Technology and eleven engineering societies, Sherman Hotel, Chicago, Ill. Oct. 19-20

Midwest Conference of the American Society for Quality Control, Chase-Park Plaza Hotel, St. Louis, Mo. Oct. 19-20

Forum on Legal and Practical Questions Raised by Computer Use, sponsored by American Bar Association and Joint Committee on Continuing Legal Education, American Law Institute, Pick-Congress Hotel, Chicago, Ill. Oct. 19-21

Second New York Conference on Electronic Reliability, Institute of Radio Engineers, NYU College of Engineering, University Heights, N. Y. Oct. 20

National Fluid Power Association, Fall Meeting, Sheraton Hotel, Philadelphia, Pa. Oct. 22-25

East Coast Aeronautical and Navigational Electronics Conference, Institute of Radio Engineers, Lord Baltimore Hotel, Baltimore, Md. Oct. 23-25

International Symposium on Aero-Space Nuclear Propulsion, sponsored by IRE, AEC, NASA, Hotel Riviera, Las Vegas, Nev. Oct. 24-26

1961 Computer Applications Symposium, sponsored by Armour Research Foundation, Morrison Hotel, Chicago, Ill. Oct. 25-26

1961 Electron Devices Meeting, Institute of Radio Engineers, Sheraton Park Hotel, Washington, D. C. Oct. 26-28

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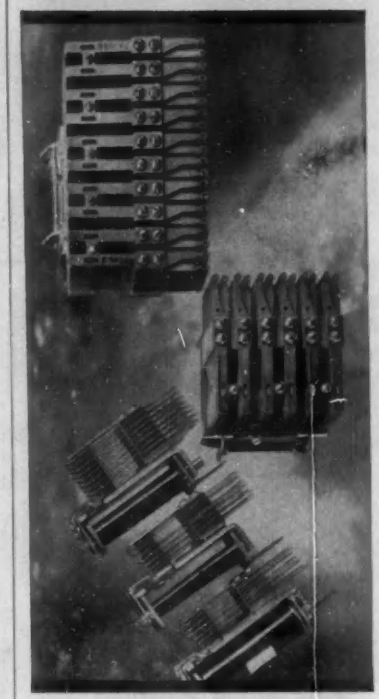

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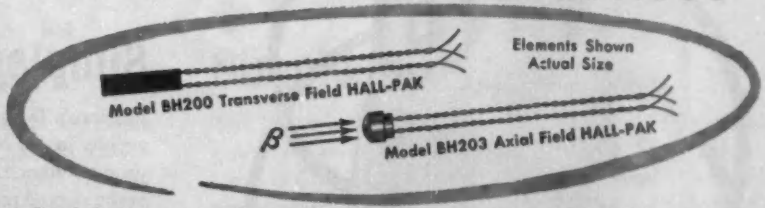

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The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Single copies of any reprint can be obtained at the nominal cost listed below by circling the corresponding numbers on a reader service card, p. 165. Don't send money with card, we will bill you later. For multiple copies write Reprint Dept. Quantity rates will be quoted on request.

513—Measuring With Solid State Transducers, 16 pp. Contains all articles from the Measurement section of Control Engineering's September 1961 theme issue on Solid State in Control. Covers piezoelectric and piezoresistive strain gages, Hall effect transducers, semiconductor thermometers, and a number of devices for sensing radiant energy based on various solid state phenomena. Variables that can be measured with such transducers include

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512—Ready Reference Data Files—IV, 20 pp. Contains Data Files 37 to 48. Subjects range from information display to semiconductor voltage regulators to loaded parallel-T filters. 50 cents.

511—Industrial Process Chromatographs: What they do, How they work, Who makes them, 14 pp. Reviews basics of chromatographic techniques including latest refinements to increase sensitivity and reduce analysis time of this versatile stream analyzer, describes major components and their functions, and highlights operation and specific features of six commercially available chromatographs. 50 cents.

510—The Use of Digital Computers in Science, in Business, and in Control, 112 pp. A collection of 14 articles published over a two-year period as the Digital Applications Series. Prominent authorities cover the application, programming, overall system design, and commercial availability of digital computers in all phases of business, industry, and military. (An old reprint but with basic and practical content of value today). $3.00.

509—Applying Incremental Servos, 24 pp. Incremental servos offer many advantages in closed-loop systems. A grouping of five basic articles compares stepping and stepless control, describes the operation and analysis of solenoid-ratchet and phase-pulsed synchronous steppers, shows 16 applications of stepping motors, tabulates pertinent characteristics of available step-

(*Continued on page 188*)

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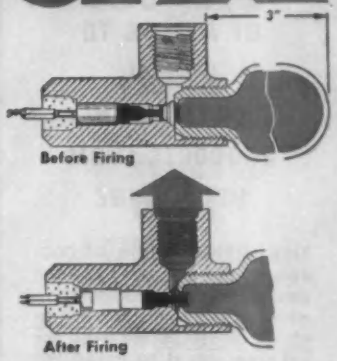

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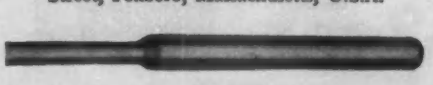

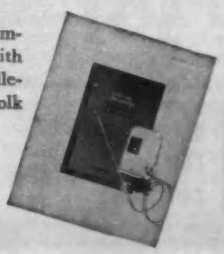

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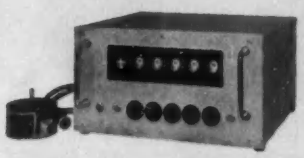

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ping motors, and discusses the problems of interlocking the devices. 65 cents.

508—Transistor Switches for Industrial Service, March 1961, 24 pp. Industry requires reliable, inexpensive, and fast switching devices. This special report thoroughly covers one possible solution to this requirement—transistor logic modules packaged for industrial use. Topics include how transistors perform logic functions, available systems and components, tips on selection and use, and case studies of industrial applications. 65 cents.

507—Tips on the Use of Electromechanical Relays, 24 pp. Compilation of five articles presents practical information on the design, test, and use of relay control systems. Topics covered include: testing relay electrical reliability, improving system reliability, narrowing relay differential, logical synthesis of systems, and verifying relay control circuits. 65 cents.

506—What You Should Know About Adaptive Systems, 17 pp. Is there such a thing as an adaptive control system? What approaches have been taken? What does the future hold? These are the questions the author answers in this three-article reprint, in sufficient detail and with sufficient references to provide a basic grounding in this latest area of control engineer interest. 50 cents.

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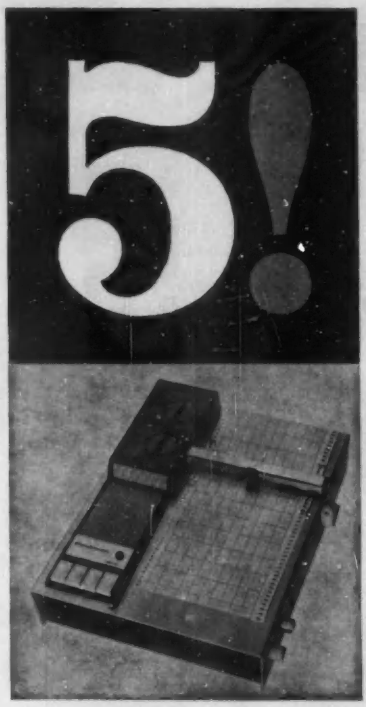

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reprint describes the development of the optimum switching criteria, and outlines the progress that has been made in implementing this theory with hardware for second order and higher order systems. Extensive references provide a guide for further study. 50 cents.

504—System Characteristics of Modern Guidance Techniques, August 1960, 22 pp. In this special report five experts from three companies cover the system characteristics of inertial navigators, guidance radars, Doppler radar techniques, modern techniques in celestial navigation, and perceptive guidance systems. 65 cents.

503—How to Determine Stream Analyzer Dynamics, 8 pp. Package of two articles shows how analyzers can introduce dynamic errors, how to determine analyzer dynamics, and how to improve performance. The instrument used is a differential refractometer but techniques can be extrapolated to other types of analyzers. 40 cents.

502—Survey of Dynamic Display Techniques, 20 pp. The function of these newly developed techniques is to put up-to-date information in the hands of human operators of control systems when the information changes at a high rate. Both basic approaches and commercial hardware are discussed for cathode ray tube displays, optical systems, and miscellaneous devices ranging from TV pickup to matrix cells. 50 cents.

501—Six Transducers for Precision Position Measurement, May 1960, 6 pp.

(Continued on page 191)

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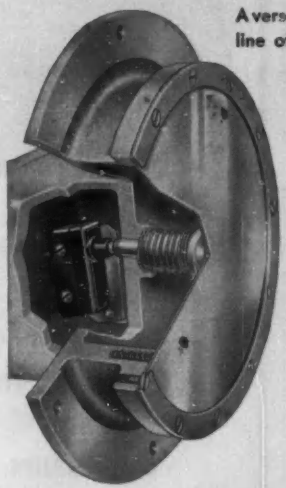

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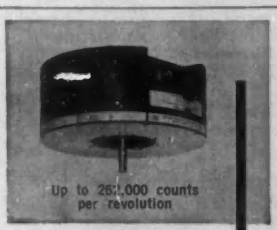

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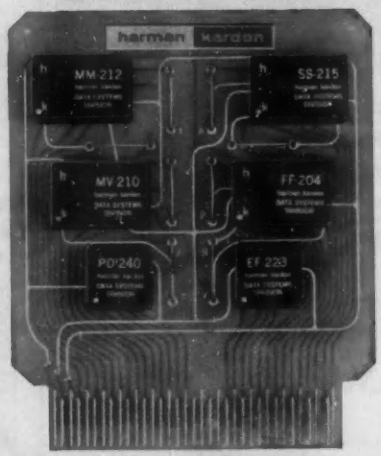

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496—How to Specify Instrument Accuracy, 8 pp. This basic reprint is aimed at helping the user and maker to develop clear and mutual agreement on allowable instrument errors. Discussions of uncertainties of zero, scale factor, and instantaneous slope aid in the intelligent specification of allowable errors and preferred test procedures. 40 cents.

494—How to Use the Root Locus in Control System Design, 12 pp. Another reprint that translates theory into practice. Eight simple rules make locus construction easy, even including the effects of distance-velocity lags. Articles show how to interpret the locus diagram, determine transient response, and use locus techniques with multiloop systems. 45 cents.

489—Fundamentals of Multivibrators, 12 pp. Multivibrators are the electronic equivalent of the double-throw electromechanical relay and can perform substantially the same functions (memory, logic, gating, counting), but at enormously higher speeds. They can be built around vacuum tubes, transistors, square-loop magnetic materials, neon tubes, thyratrons, and cryotrons. This covers a broad selection of multivibrator circuits. 45 cents.

488—A Roundup of Control System Test Equipment, 24 pp. Specialized control system test equipment divides into three classes: 1) devices that only generate a test signal, 2) systems that both disturb the system and provide a means for evaluating response, and 3) devices that only evaluate control system response. 60 cents.

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*These advertisements appeared in the September issue.

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CITY..... ZONE..... STATE.....

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PROFESSIONAL DEGREE(S) .....

MAJOR(S) .....

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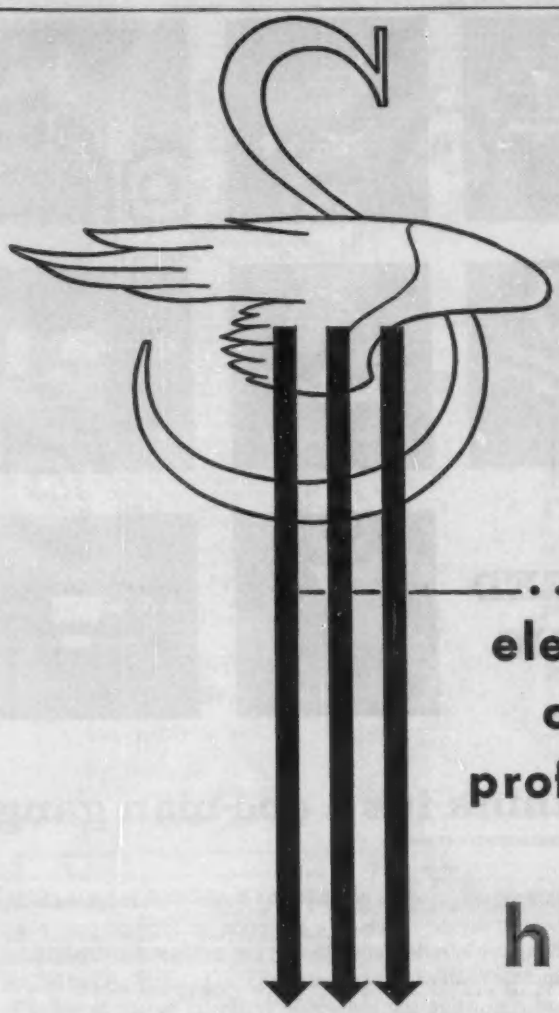

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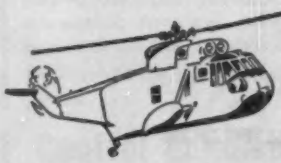

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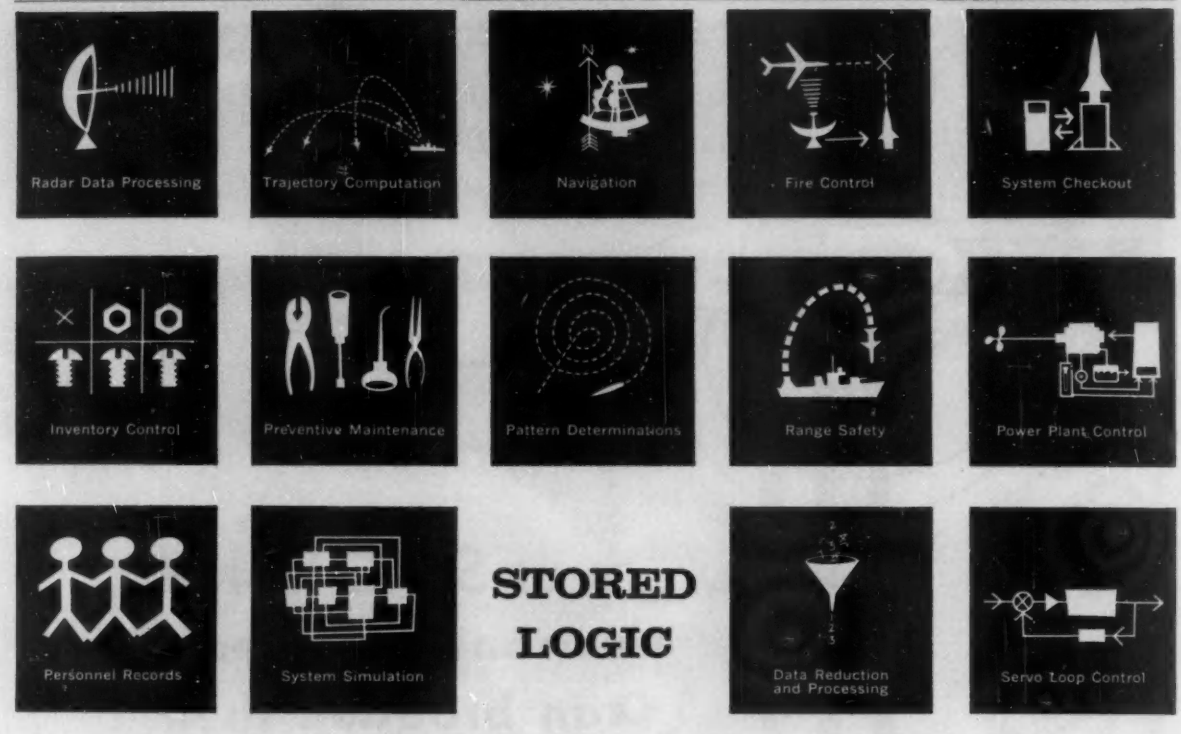

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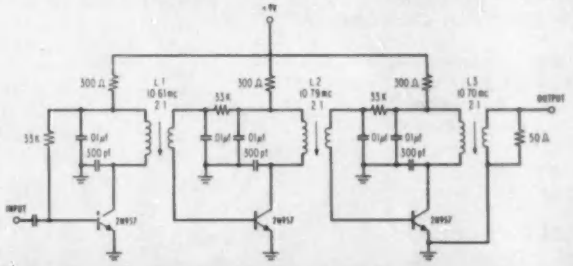

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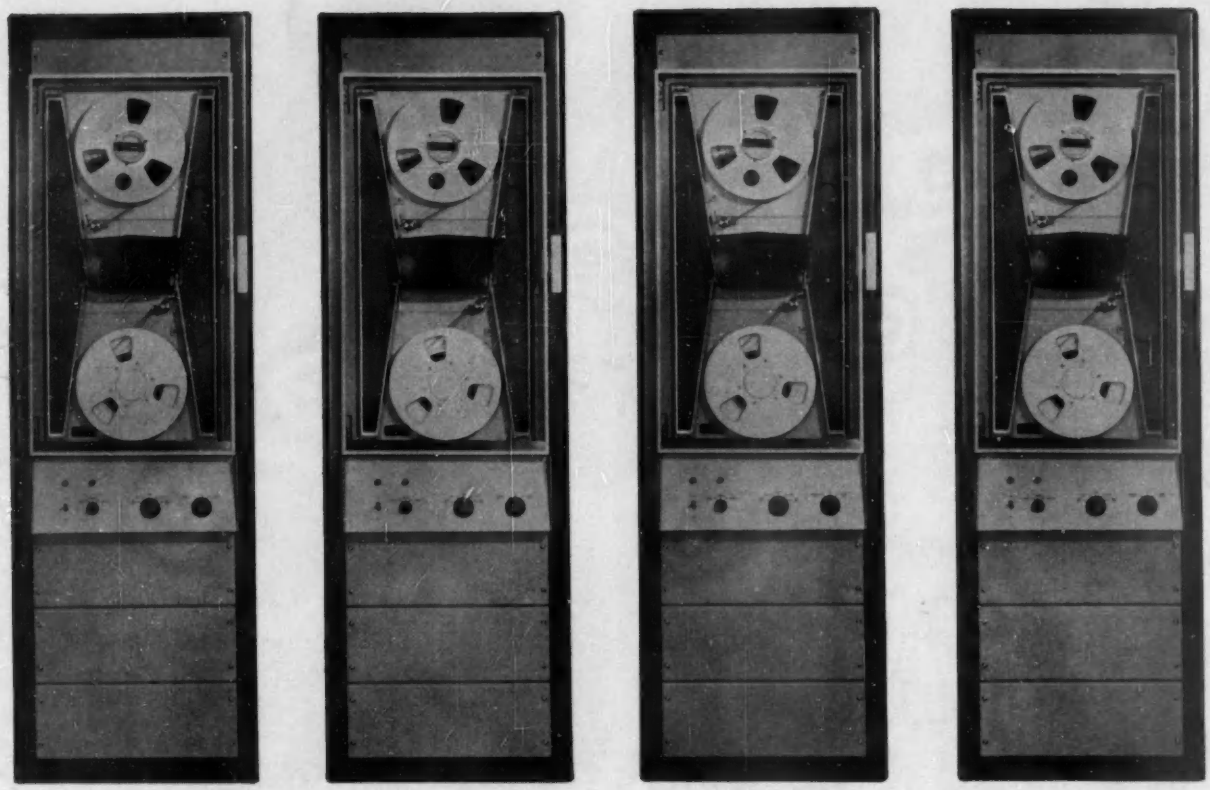

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